PHD

Cost-benefit analysis within a sustainable development paradigm: an application to a production system

Tabche, Ibrahim

Award date:
2002

Awarding institution:
University of Bath

COST-BENEFIT ANALYSIS WITHIN A SUSTAINABLE DEVELOPMENT PARADIGM: AN APPLICATION TO A PRODUCTION SYSTEM

Submitted by Ibrahim Tabche

For the degree of Doctor of Philosophy of the University of Bath

2002

TABLE OF CONTENTS

TABLE OF CONTENTS - Continued

TABLE OF CONTENTS - Continued

TABLE OF CONTENTS - Continued

Page

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES - Continued

ACKNOWLEDGEMENTS

I am grateful to my advisor Dr. Adrian Winnett for his valuable advice and recommendations throughout this work. His support has proved to be quite helpful in overcoming many of the obstacles faced during this research.

Thanks are also due to Dr. John Henning of McGill University, Montreal, for his earlier comments on the initial chapters of this manuscript.

I am also thankful for Ms. Deborah Viskelis for her help in data collection.

The strong encouragement of my parents has been essential especially when it was tempting for me to quit. For this, I am forever grateful and would like to dedicate this work to them.

And last, I am grateful for my family's support; wife and children, who willfully accepted to give me the time to work on this research, enduring the difficulties of my long absence. I do hope to be able to make it up for them in the future.

ABSTRACT

Cost-Benefit Analysis (CBA) is a widely used monetary appraisal technique that involves the quantitative evaluation of a project's net economic benefits. CBA provides guidance to decision-makers, and aids policy makers in public sector agencies in ranking projects and determining the most profitable ones. However, many researchers believe that, when used conventionally, the technique is incapable of fully accounting for the values of sustainable development as CBA falls within the paradigm of neoclassical economics that emphasises economic efficiency and market processes as the major management mechanism.

The World Commission on Environment and Development (1987) defines sustainable development as a "development that meets the needs of the present without compromising the ability of future generations to meet their needs". CBA is accused of misjudging projects with relevant environmental costs and benefits, thus possibly contributing to policies that may degrade natural capital.

These projects include modern industrialized agriculture, which has been accused of being detrimental to the environment, causing problems that threaten the productive capital base that sustains economic production. Additionally, it is accused of causing negative impacts on human health and contributing to the disintegration of many rural communities around the world.

Within the paradigm of sustainable development, sustainable agriculture practices in general and organic farming in particular have increasingly been seen as an alternative by many farmers in the EU and North America in the last few decades to counter such effects.

However, a wider conversion to sustainable practices and the establishment of supportive governmental policies require suitable tools and techniques that can properly reflect the integrative advantages of organic farming and its pursuit of sustainability, and at the same time, facilitate the comparison between various farming systems. This has often been hampered by the difficulty in understanding and quantifying the various interrelated impacts given the complex ecosystem among other issues.

The aim of this research is to suggest extensions to the traditional CBA analysis using a selected multi-dimensional framework and a set of indicators that reflect sustainability within different farming systems. These include land degradation, water pollution, health aspects and on-farm employment. The extensions include, in addition to internalising many of the relevant environmental and social impacts, the usage of a lower-than–the market discount rate and the introduction of a system of weights for various impacts.

The results presented confirm that the extended analysis is likely to better reflect the economic and societal benefits of the organic production system than the standard analysis. Additionally, they show that the organic model offers economic gains to the society in excess of its financial private benefits, and that these net economic benefits are greater than those of the comparative conventional production model.The results

were confirmed using an extensive sensitivity analysis that investigated a wide variation in parameters.

The modifications were carried out from within, broadly, a market framework, by using market valuation techniques and by re-visiting the underlying, standard economic assumptions.

The extended analysis has been shown to more adequately reflect various sustainability objectives within farming operations, and is therefore, expected to provide an improved assessment tool to support various policy interventions aimed at environmental preservation and a better comparison of various farming systems. The extended CBA may still not be a perfect tool but it is too useful to be avoided. Combining the results with other decision tools such as EIA or MCA will improve the decisions. Hence, the research is expected to enrich the intellectual debate and contribute to the efforts in moving sustainable development into a more operational context, which will help sustainability objectives form a guide for many development initiatives.

LIST OF ABBREVIATIONS

a.i.	Active ingredients
C$	Canadian Dollar
CBA	Cost-benefit analysis
CREAQ	Committee for Economic Reference on Agriculture
cu.m	Cubic meter
EU	European Union
GM	Green manure
ha	Hectare
hr.	Hour
km	Kilometre
lit	Litre
m	Metre
mg	Milligram
ng	nanogram
SLR	Saint-Laurent river
sq. m.	Square metres
ug	microgram
USA	United States of America
WTAC	Willingness to accept compensation
WTP	Willingness to pay

CHAPTER 1
INTRODUCTION

1.1. Introduction/Problem Definition

The Cost-Benefit Analysis technique (CBA) is widely used in the evaluation of projects' economic feasibility. It is a monetary appraisal technique that involves the quantitative evaluation of a project's net economic benefits. Using a discounting process, costs and benefits of different time periods are transferred into a common temporal basis of measurement (discounted monetary value) and are then analysed.

It is believed that this technique was first developed in the United States in 1936[1], in response to a legal requirement imposed on the federal government's water resource projects (Hufschmidt *et al.*, 1983). Since then, applications of this technique to other areas have increased to include transportation, urban development, electric power, health, education, welfare, environment-related projects and in the assessment of policy initiatives, to name a few.

CBA helps to provide guidance to decision-makers, and aids policy makers in public sector agencies in ranking projects and determining the most profitable ones. Furthermore, by analysing the various costs and benefits associated with a project, CBA helps to reveal a project's weak points and any critical variables that affect its profitability.

However, many researchers believe that, when used conventionally, the technique is incapable of fully accounting for the values of sustainable development, especially in the evaluation of projects with relevant environmental costs and benefits. Thus, it would undervalue environmental resources resulting in decisions that may cause the degradation of natural capital.

Of these cases, sustainable agriculture is one example where conventional economic assessment is likely to fail in showing the true values of the benefits and costs involved. As a result, this will affect the production decisions of many farmers, and may result in reduced support by both government and credit agencies.

---

1 Wolfson (2001) claims that a somewhat similar approach was endorsed by the US government in the River Harbor Act of 1902.

Since economic considerations are central to the decision of most farmers to adopt sustainable practices, an economic assessment that better reflects sustainability within farm operations could possibly be expected to show improved net benefits and therefore, reinforce the case for resource conservation.

1.2. CBA, Economic Analysis and Sustainable Development

The World Commission on Environment and Development (1987) has defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their needs." [2]

Two issues are implied here. First, a type of growth is proposed that considers minimum damage to the resources upon which human beings depend to meet their needs, including the environmental ones (i.e. sustainable resource use); and second, the benefits of this growth have to be distributed fairly to both current and future generations (i.e. inter-generational equity).

While CBA has been extensively used in project evaluation and was even a requirement to assess certain public regulations in some countries (e.g. the United States)[3], many researchers have criticized the technique as being inadequate to incorporate and fully reflect some of the broad values embedded in the spirit of sustainable development (Henderson, 1981; Ekins, 1986; Soderbaum, 1987). Partly this was attributed to the economic paradigm in which CBA operates within, and also because of some of the assumptions underlying the process.

CBA falls within the conventional (neo-classical) economic paradigm, which many critics asserted that it has traditionally served different objectives and priorities than those of sustainable development, because it focuses mainly on market mechanisms and economic efficiency as a sole decision criterion. This is illustrated in the following arguments.

---

[2] There are other equally relevant definitions; some estimate it to be several hundred definitions (Jacobs, 1995; Bosshard, 2000). The one mentioned above, albeit being general, is believed to be the best known and is the one most widely used.

[3] Mr. Reagan, the president of the United States of America between 1980 and 1988, issued an Executive Order (No.12291) in 1981, making CBA a requirement for all major rules i.e. to use it to defend proposed regulatory changes (Tietenberg, 1992). This was reaffirmed later by President Clinton in 1993 (Executive Order 12866).

Many critics of conventional neo-classical economic theory assert that it often does not or fails to properly account for non-marketed[4] (mainly environmental and social) goods[5] and services. This includes many natural amenities such as clean air and water. These resources were once considered to be common property and were available in unlimited supply. As common property, there was no market to set costs, consequently, economists and policy makers treated them as free goods and priced them at zero cost. This incorrect valuation is believed to have increased the rate at which such amenities/resources are used and has resulted in negative impacts on the environment (land, water, air etc.) and the society. Environmental issues such as land degradation and water pollution have been treated as externalities whose costs to the environment and society were often not central to the analysis and were somewhat disregarded. However, such externalities do affect the welfare of many in society and increase production costs. This "omission" is an error, because by not accounting for these costs as part of the private costs, they are transferred to society's current and future generations at large.

In addition, the conventional paradigm largely ignores the need for sustainable rates of resource use due to the belief in continuous technological change (that will lead to an increased efficiency of resource use) and high substitution possibilities (between natural capital and between natural and man-made capital), that will sustain the system within its carrying capacity limits (Costanza, 1994). However, this misconception, it is claimed, has resulted in problems of resource degradation and irreversible damage in many countries around the world.

The values implicit in CBA are utilitarian. The aim is to maximise net monetary benefits (called economic efficiency by Tietenberg, 1992; or allocative efficiency by Carter and Lohr, 1986) at the expense of other objectives and to whomever the benefits accrue[6], without regard to their distribution, an issue which is thought by most neo-classical economists to be best left to the political process (Costanza, 1994). Norgaard (1991) takes somewhat an extreme stand by claiming that the focus on economic

[4] They are also not easily quantifiable in monetary terms.

[5] "Goods are dealt with in accordance to their market value and not to what they really are." (Schumacher, 1973, pp. 36)

[6] "The greatest good for the greatest number", according to Jeremy Bentham.

efficiency is rooted in the implicit assumption that current generations hold all the rights to resources and should efficiently exploit them. In reality, current generations seem to place less importance on the interests of future generations. However, in public policy, intra- and inter-generational distribution of costs and benefits must be given more attention, from both social and moral perspectives. Sustainable development concepts call for efficient allocation of resources over time, but also emphasize equity criteria through the distribution of resource rights between generations.

In addition, CBA is based on the Kaldor-Hicks principle of potential compensation. In theory, using traditional analysis, project "A", for example, might be superior or preferable to project "B" if the gainers of project “A” could compensate those who lose and still be better off[7]. While this implies that a suitable (potential) compensation exists that leaves no one worse off, it does not require actual compensation of the losers by the gainers. This, again, touches on the issues of equity, trade-off and social welfare[8].

Furthermore, CBA has also been accused of concentrating only on ends (the results of analysis) and ignoring the process (means) (Schulze and Howe, 1985). Thus, CBA may inadvertently favour a project with higher net present benefits even if the project is accompanied by a major or an irreversible (environmental) damage. Clearly, from the sustainable development viewpoint, this is unacceptable. The process itself is important and is concerned with issues of conservation and preservation as well as social justice. A project should avoid the depletion of non-renewable resources, and the excessive use and degradation of renewable resources to the disadvantage of future generations.

In summary, the three main criticisms of CBA techniques as commonly perceived are listed below.

A. Limited Scope

CBA has been criticized for having a limited scope when it comes to judging the wider environmental and societal aspects of projects. Environmental issues are multi-

---

7 In Welfare Economics, CBA helps to show whether a potential Pareto-improvement exists. This is a situation where a change could make, after compensation, at least one person better off and no one worse off.

8 Some economists have suggested integrating efficiency and equity with the introduction of weights to different arguments in the analysis in order to derive a single-valued measure of benefits/costs. However the optimal manner to derive such weights has been a contentious issue.

dimensional (physical, social, and cultural), multi-disciplinary, and inter-temporal. In addition, they involve many uncertainties and irreversible damage. An adequate analysis must consider all of these factors.

B. Monetary Valuation

CBA requires that all impacts are reduced to their equivalent monetary terms and then analysed. This involves at least two problems: the difficulty of valuation and the correctness (appropriateness) of such valuation.

First, several issues such as environmental quality, amenities (scenery, habitat conservation, biodiversity etc.) and human health or even changes to them (costs/benefits) may not be as tangible as pollution or deforestation and are, therefore, difficult to measure/value. In addition, they do not have markets to determine their prices[9] (i.e., are not traded on the markets). The difficulties in ascribing physical and monetary values have led analysts, in many cases, to omit these issues (Hall *et al.*, 1992). This has been particularly problematic when CBA was used as the main policy tool in governmental regulations (in the US) rather than a decision aid and a single component of the decision-making process (Wolfson, 2001). These omissions have resulted in incomplete analysis and may have increased the pressure on environmental resources. In other cases, analysts have resorted to indirect valuation techniques to determine shadow or implicit prices. While this has worked in many cases, the valuation process remains a difficult and controversial issue[10].

Second, users of conventional CBA assume that a correct valuation of impacts can be reached. This, however, is not always the case from scientific, ethical and social points of view. For example, placing a monetary value on human life or clean air has often been criticised since it might be argued that these have to be preserved regardless of costs (Adler and Posner, 2001). Additionally, ecological and environmental impacts may not be completely understood and may be essentially unpredictable. Societies have different sets of values and therefore may value the same issue differently. Furthermore, there is often no consensus in society about valuation rules (Mishan, 1982). These factors may have contributed to under-estimating the significance of environmental damage in many cases.

[9] Market prices could also reflect part of the real/total value (the World Bank, 1998).

C. The Discounting Process

The discounting process used in conventional CBA, advocates a preference for present benefits and future costs, to future benefits and present costs. Present impacts are weighed more heavily, so that projects with early benefits and later costs are favoured. This will induce the current generation to act in a way that results in a non-equitable distribution of resource benefits to the disadvantage of future generations.

The above points are some of the main criticisms of CBA as commonly practiced, which reflect practical and methodological limitations of the technique. While some are significant, it is believed that a better understanding of these limitations will justify the modifications required for the tool to better reflect sustainable development values. Still, CBA remains a vital decision tool, which has great value in informing and guiding decisions, and has the potential to evaluate projects with environmental impacts.

1.3. Sustainable and Organic Agriculture: An Overview

The shift to intensive cropping practices, highly mechanised agricultural production, and the extensive use of synthetic chemical inputs, have contributed to increased land degradation, air and water pollution and health problems in many regions of the world. As a consequence, these problems have resulted in both reduced yield and associated losses in farm income and other related costs to the societies. This degradation will eventually affect the natural agricultural resource base, and if it is not stopped it will probably have harmful effects on future generations.

In response to this situation, many farmers in the EU and North America have accelerated their conversion to more sustainable agricultural practices, particularly organic farming, over the last 25 years[11]. It is estimated that currently an average of 2.2% of the agricultural land in the EU is used for organic production. The figure is

[10] It is believed that one of the main difficulties in applying the concept of sustainable development at the project level arise from operational problems of measurement and valuation (Morvaridi, 1994).

[11] Within the recent history, organic farming as a concept probably dates back to the early 1920 s (e.g. biodynamic farming by Steiner, 1924), however, the first to use the term organic farming may have been Northbourne in 1940.

much higher for some countries like Denmark (5%) Austria and Sweden (10%) (Hansen *et al.*, 2001). In the UK, the area of organic and in-conversion land is believed to have doubled between 1999 and 2000 (Rigby and Caceres, 2001). There is a similar trend in North America. In the USA, the number of organic farmers is increasing at a rate of about 12% per year (USDA, 2000). In Canada, Agriculture and Agri-Food Canada (2001) estimates that there are approximately 2000 organic farmers occupying a total area of 165,000 hectares. Canada is considered to be among the top five world producers of organic grains and oilseeds with an estimated retail value of C$1 billion (including processed products). Additionally, 4.9% of the fruit and vegetable farms in Canada consider themselves to be organic producers (Agriculture and Agri-Food Canada, 2001). This sector is also active in the Canadian province of Quebec. The Ministry of Agriculture of Quebec (MAPAQ, 1993) estimated that in 1992, 11% of Quebec farmers practiced some organic farming. In 1996, there were about 501 certified organic enterprises occupying an area of about 13,000 hectares (Canadian Organic Growers, 1997). The above figures reflect a rapidly growing agricultural sector in these countries.

Organic farming has been defined by MacRae *et al.* (1989) as based on "designs and management practices that work with natural processes to conserve all resources, promote agro-ecosystem resilience and self regulation, and minimize wastage and environmental damage while improving farm profitability". However, this definition applies to systems that involve a wide spectrum of practices, most of which share the following activities within the definition of the USDA, as quoted by Lampkin (1990) in his reference book on the subject: "An organic farming system is a production system which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators and livestock feed additives. To the maximum extent possible, organic farming systems rely on crop rotations, crop residues, animal manure, legumes, green manure, off-farm organic wastes and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients and to control insects, weeds and other pests". Lampkin (1994) added new aspects related to the integrative role of organic farming as follows: "to create integrated, humane, environmentally and economically sustainable production systems, which maximize reliance on farm-derived renewable resources and the management of ecological and biological processes and interactions, so as to provide acceptable levels of crop, livestock and human nutrition, protection from pests and disease, and an appropriate return to the human and other resources". A further expansion of the aim and scope of organic agriculture to include social aspects was offered by the International Federation of Organic Agriculture Movements (IFOAM, 1998) as follows "to include the wider social and ecological impact ..... to allow everyone involved in organic production and processing a quality of life which meets their basic needs and allows an adequate return and satisfaction from their work, including a safe working environment....and to progress toward an entire production, processing and distribution chain which is both socially just and ecologically responsible".

Therefore, these agricultural systems are designed to maximize the use of existing soil nutrients and beneficial organisms, water cycles, energy flows and natural pest controls, and are widely perceived to produce healthy and nutritious food, and to be less damaging to the environment and human health. Moreover, they aim to minimize dependence on non-renewable resources, (mainly synthetic and petroleum based products, including most pesticides and certain fertilizers) and favour the use of naturally occurring products and processes[12], while at the same time, considering social aspects.

The expansion and interest in this market reflects a growth in the consumer demand for environmentally friendly and potentially safer food products (Rigby and Caceres, 2001). Producers may have also been motivated by environment and health concerns, lifestyle or holistic reasons, but some farmers may have been attracted by the sometimes improved economics of organic production relative to conventional, especially with the presence of lucrative price premiums for organic produce, which may reach up to 100% for some vegetables and cereals, for example, in the UK (Lampkin and Measures, 1995).

Organic agriculture falls within the sustainable agriculture framework mainly as it entails the conservation of available natural resources and reduction in potential health impacts. There is no unique definition of sustainable agriculture[13], but a fairly

---

[12] Biological control for pests, for example.

[13] Conway (1997) reports that sustainable agriculture is an "all-embracing term" that means different things to different people (e.g. agriculturists, economists, environmentalists, sociologists etc).

comprehensive one is the definition offered by Ikerd (1993) as a system that " is able to provide for food and fiber needs of society, must meet the needs of current generation, ... must be capable of maintaining its productivity and usefulness to society over the long run ..... must be environmentally-sound, resource-conserving, economically viable and socially supportive, commercially competitive, and environmentally sound". Most definitions share four general aims: sufficient food and fiber production, environmental stewardship, economic viability and social justice (Allen *et al.*, 1991; Crews *et al.*, 1991; Kirchmann and Thorvaldsson, 2001). Despite similarities and differences in various definitions, many scientists believe that sustainable agriculture should be regarded as a process toward achieving a continuously evolving goal[14], rather than a prescribed set of practices, tools or inputs, and that sustainable practices will vary temporally and spatially and should therefore be assessed in the context in which they are used given the local conditions, and the agricultural and ecological history of an area (Rigby and Caceres, 2001). The above definition covers many approaches to farming systems such as integrated pest management, integrated crop management, low input sustainable agriculture, agroecology, permaculture, biodynamic farming and organic farming, to name a few. However, the focus in this research is on organic farming.

Since economic considerations are central to the decisions of most farmers to adopt organic and sustainable practices, an economic assessment that shows a positive net return can thereby promote resource conservation, and is likely to provide a motive for enhanced support to sustainable production practices by both government and credit agencies.

The purpose of this research is to respond to CBA criticisms and to use a modified CBA model to perform a more appropriate analysis of sustainability within farm operations. This modified CBA will then be applied to a comparison of conventional and organic vegetable production operations in Quebec.

[14] The goal must be refined as knowledge and attitudes change (Rigby and Caceres, 2001).

1.4. Hypothesis

The use of an extended cost-benefit analysis that includes environmental and social impacts associated with conventional and organic farming production practices will better reflect (some of the) values of sustainable development, and will therefore more correctly estimate the net benefits from organic as compared to conventional vegetable production to the society in Quebec in the long-run.

1.5. Objectives of the Study

1. To use an extended i.e. a more environmentally sensitive cost-benefit analytical framework to better account for selected sustainable development concepts. These include: 1) inter-temporal allocative efficiency that better promotes resource conservation and incorporates equity issues; and 2) the multi-dimensional objectives and inter-disciplinary (i.e. social and environmental) implications of a project (farming, in this case).

2. To operationalize this framework in a comparison of conventional and organic production of vegetable crops in Quebec.

1.6. Scope of the Study

The extended analysis will be applied to compare organic and conventional production of the main vegetable crops produced on a typical farm in the province of Quebec. The analysis will consider the following priority impacts: 1) environmental, such as land degradation and water pollution, 2) social, namely on-farm employment and human health issues, and 3) economic, which consist of financial net revenues from production.

The methodology will be developed using advances reported in European and North American literature, and operationalized using a combination of primary and secondary production data, including data obtained from direct interviews with organic farmers and experts in Quebec, as well as information available in databanks and other relevant publications (AGRITEL, CREAQ, UPA, CDAQ, SANET, USDA... etc).

1.7. Significance of the Research

The importance of this research lies in the attempt to incorporate values of sustainable development into the present CBA framework and thus address some of its current deficiencies for such applications. This type of work, considered to be part of the effort toward improved environmental accounting and decision making in resource-related projects, is currently being undertaken by many researchers in several European and North American institutions (Statistics Canada, Environment Canada, the World Bank and OECD among others). It is hoped that this work would contribute to the intellectual debate and result in an improved understanding of this field and increased awareness of environment-conserving practices.

The following points summarise the significance of this research:

- This research represents an attempt to use an extended cost- benefit analysis technique to allow its application to the analysis of sustainability within farm operations (production systems). This approach answers criticisms about the non-suitability of CBA for this kind of work.

- The extended analysis, with its integrated and comprehensive analysis of (various) impacts, could be used as an improved assessment tool as it aims to reach a single indicator, i.e. a monetary value of relevant impacts. The need for the development and application of integrative evaluation tools, to assess various impacts of sustainable agriculture, is growing as the adoption of sustainable farming systems has widely increased in the last decade. Such a tool can help decision-makers and planners to formulate appropriate decisions and policies in the management of natural resources[15] and contribute to efforts toward achieving a more sustainable development.

- This research will help to better show the main net benefits of organic as compared with conventional production from societal and environmental perspectives. If these benefits are positive, it is hoped that this may lead to a policy conclusion (and perhaps future programs) to promote the conversion to sustainable production and enhanced support by both government and credit agencies. While this issue is of importance world-wide, it may be particularly

[15] It can justify the introduction of various conservation policies.

important to the farmers in the Province of Quebec[16], since there has been no similar previous studies on the economics of integrated impacts of organic farming in the province.

- The research represents an application of several physical and monetary evaluation techniques to the selected environmental and social impacts. This by itself is important since many economists have been complaining about the "paucity" of studies applying these techniques (Lutz *et al.*, 1994) in general. This is also true for studies in and about Canada. The application of these techniques on a typical farm will serve as an example and case study of such application, which may lead to further micro and macro studies and contribute to the intellectual debate. This is believed to be more relevant than (solely pursuing) the accuracy of the generated figures.

In summary, it is believed that the extension of the traditional CBA, the tool that is most frequently used in project appraisal, could help many policy makers, in both developing and developed countries, to reach improved and sustainable decisions in natural resource-related projects.

16 Integrated comparative studies between the two production systems may help farmers make soundly based decisions on the implications of conversion.

CHAPTER 2

A REVIEW OF SOME OF AGRICULTURE'S IMPACTS ON THE ENVIRONMENT AND HUMAN WELLBEING

2.1. Introduction

A general and brief discussion of the nature of some of the main environmental and social impacts associated with conventional agricultural practices[17] is presented in this chapter. This includes the causes of land degradation, water pollution, as well as certain social impacts such as on-farm employment and health issues. These impacts are the ones that will be mainly covered in (later parts of) this research. A fuller discussion here is believed to be impractical and somewhat beyond the scope of this research. A reference to the situation in the Province of Quebec is often made in this chapter, but an extensive review of relevant impact studies is presented in Chapter 5. A brief literature review of the impacts of organic farming systems is also presented at the end of the chapter.

2.2. Impacts of Conventional Agriculture

Conventional agriculture can be defined as a production system that employs a full range of pre- and post planting tillage methods, synthetic fertilizers, pesticides, antibiotics and hormones (Cacek and Lagner, 1986). As such, it is often criticised as being too reliant on technology, petroleum-based inputs, and credit; too specialised and ecologically unsound; and too dependent on government subsidies (Batie and Taylor, 1989).

The high reliance of (modern) agriculture on mechanisation, technology and chemicals has resulted in significant gains in farm productivity to levels not witnessed before. While this has brought abundance of agricultural produce, lower prices to consumers and income to the producing countries, such advances have often been accompanied by many significant social and environmental problems.

[17] It should be noted that many sustainable practices, such as tillage and (excessive) organic chemical use etc when improperly performed, could also contribute to negative on and off-farm impacts.

Many modern production techniques are capital and energy-intensive as they rely heavily on machinery. This has favoured and promoted economies of scale, which has resulted in increased levels of concentration in the product market in many developed countries. This is more obvious in countries like the USA and Canada where over the past 50 years fewer numbers of farms have been providing most of the agricultural products. Such concentration has affected small farmers who have found themselves incapable of competing against large farms. This has contributed to the increasing trend of migration from rural areas in many countries, resulting in a declining economic base in rural communities and a continuing loss of family farms and lifestyles.

Additionally, intensive cropping practices tend to be mono-cultural and heavily dependent on synthetic chemicals. This has caused many environmental problems such as land degradation in various forms, surface and ground water pollution (caused by farm chemicals and sediments) and air pollution from volatile chemicals. These impacts have affected farm productivity and monetary returns to farmers in many countries, and have had negative consequences on human and animal health within and beyond farm gates. Part of these health impacts is attributed to the increasing accidents (and risks) to farmers applying the chemicals, and to the increasing consumption of chemically contaminated food and water, some of which is claimed to have chronic effects. These impacts may also cause negative effects on the ecosystem balance and integrity (wildlife habitat, biodiversity, flora and fauna etc) and affect the quality of natural environments and resources. A simplified overview of conventional agriculture's main negative impacts on environment and health is presented in Figure 2.1.

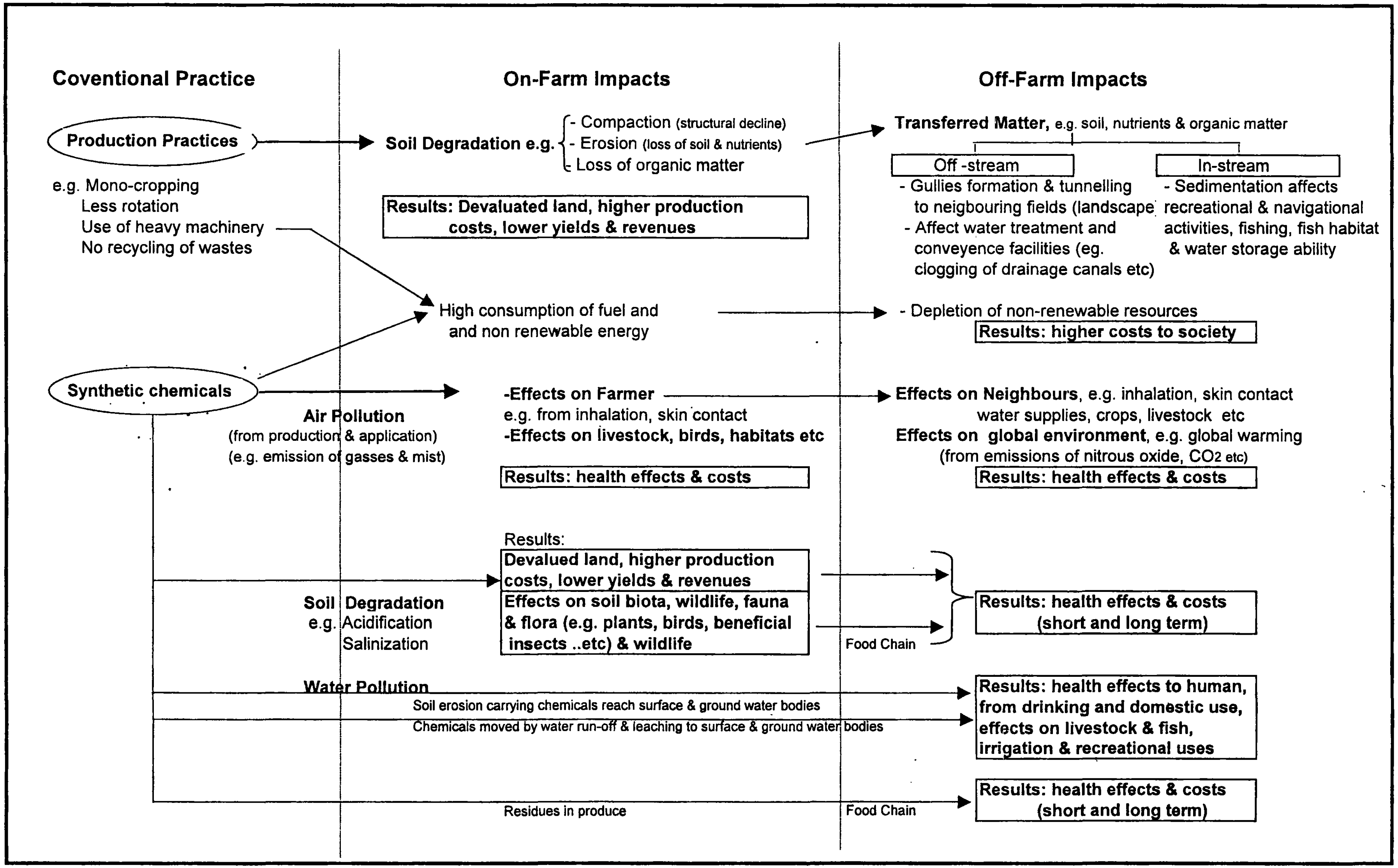
If left uncontrolled, environmental problems affecting the agricultural resource base, can eventually have a significant impact on the economies of many countries that depend on or have an active agricultural sector[18].

2.3. Environmental Problems

While there is a number of environmental problems that have been linked to conventional agricultural practices, the discussions in this study will focus on two main

[18] In Canada, for example, the agriculture and food processing sector accounted for 4.2% of gross domestic product (GDP) in 1998 (Agriculture Canada, 1999).

Figure 2.1: Impacts Pathway of Conventional Agriculture on Environment and Health



environmental issues as key indicators of the broader range of impacts: land degradation and water pollution.

2.3.1. Land Degradation

Declining agricultural land quality is a problem facing several countries around the world including Canada (and the province of Quebec). Land degradation occurs largely in the forms of soil erosion, compaction, salinization, acidification and loss of organic matter.

The loss of soil quality results in reduced crop quality and yield, and requires increased applications of production inputs and corrective measures to maintain productivity and offset physical damage. Furthermore, degraded agricultural land has lower monetary (selling) value than well-managed land.

In Quebec, it is believed that the most important cause of agricultural land degradation is soil compaction (Agriculture Canada, 1985; Fox and Coote, 1986; and Mehuys, 1984), affecting mainly the St. Lawrence lowlands[19] with its fine textured soil. The second major cause is erosion by water affecting the same region with various intensities depending on land slope. Erosion also affects some regions in the Eastern Townships and the North Shore (Agriculture Canada, 1985). Wind erosion affects only a small land area in Quebec (Fox and Coote, 1986; and Mehuys, 1984), but its main effect is not reduced fertility, but the destruction of vegetable seedlings on the 700 hectares of susceptible organic soils located south-east of Montreal (Mehuys, 1984). Acidification, on the other hand, is a minor problem in the province, with only small areas in Southern Quebec that are at high risk (Fox and Coote, 1986). The thawing of ice in spring and rainfall in fall are believed to be sufficient to leach any accumulated salts, and diminish the risk of salinization in Quebec (MacKenzie, 1993). More details are discussed in Chapter 5.

[19] The St. Lawrence Region is a narrow strip of land around the St. Lawrence River extending from the Ontario border to the west, the US border to the south and Quebec City to the east. This area contains about one half of all arable land in the province.

2.3.1.1. Overview of Land Degradation Processes

Land degradation can be mainly attributed to the following five processes:

1-Soil erosion by wind and water.
2-Soil acidification.
3-Organic matter loss and the associated nutrient decrease.
4-Soil compaction.
5-Soil salinization.

Additionally soil erosion can contribute to off-farm impacts. This will be discussed in Section 2.3.1.1.6.

2.3.1.1.1. Soil Erosion

Soil erosion can be defined as the movement of soil by water, wind and gravity (Wall *et al.*, 1997). However, since the effects of wind are minor in Quebec, it will not be discussed further.

Water erosion occurs mainly when the supply of rainwater or melted snow exceeds the soil's capacity to absorb it (Agriculture Canada, 1985). Consequently, the flow of water carries with it the unprotected topsoil as it flows down a slope. This topsoil often contains many nutrients and a good portion of the available organic matter.

Many conventional production practices such as frequent tillage, excessive summer-fallow and the reduction in the use of forage crops accelerate the process of soil erosion. Additional contributing practices include clean cultivation, row cropping, monoculture, cultivating up and down slopes, windbreak removal and poor manure management (Agriculture Canada, 1985).

The loss of topsoil results in soils with low organic matter, poor nutrient supply, water holding capacity and tilth, and consequently affect soil productivity in the long run. The problem can be so severe in some cases, that productivity can not be recovered completely even with corrective measures. However, changes in yield productivity as a result of erosion depends also on the crops grown, type of soil and production practices.

2.3.1.1.2. Soil Compaction

Soil compaction results from the frequent passage of heavy machinery over agricultural soils that are poorly drained and/or low in organic matter (Fox and Coote, 1986). Compaction damages soil structure and increases bulk density. Dense soils (high bulk density) are less aerated, create problems for root penetration, and subject crops to increased moisture and nutrient stress. Consequently, yield is reduced, the extent depending on factors such as soil type, organic matter content, and amount of traffic (Mehuys, 1984). Compacted soils are also more difficult and costly to cultivate.

2.3.1.1.3. Soil Acidification

Although some soils are acidic by nature (due to the soil formation processes) or because of acid rain, acidity is mainly caused by the application of nitrogen and elementary sulphur fertilizers. Nitrogen fertilizers increase acidity by leaching out basic elements and by nitrification[20].

Acidity is the soil degradation problem that is best understood, among other causes, in terms of extent, severity and means of mitigation (Fox and Coote, 1986). While it varies with soil texture, in general, sandy soils tend to be more acidic[21] (or susceptible to becoming acidic) than clayey soils (Mehuys, 1984).

The effects of acidity on yield depend on soil pH levels[22], soil type and the crop grown. Crop yield generally starts to decrease at pH levels below 5.5 (Agriculture Canada, 1985). Acidification also reduces the decomposition rate of organic matter, biological and enzymatic activity, and may damage the soil structure (Tabi et. al., 1990). At low (soil) pH, most macro-nutrients become less available to crops and some micro-elements (e.g. aluminum and manganese) may reach toxic levels to crops because of increased solubility (Nyborg and Hoyt, 1978).

---

[20] The contribution of nitrogen fertilizers to soil acidity is much greater than that of sulphur in Quebec, since the quantity of nitrogen fertilizers applied is larger (Mehuys, 1984).

[21] Soils are considered acidic if their pH level is below 7.

[22] Crops have a different tolerance to acidity, with some growing better (and are more productive) in slightly acidic soils

2.3.1.1.4. Loss of Organic Matter

Organic matter may be lost by erosion, excessive microbial activity and by improper management practices (frequent cultivation[23], summer fallowing and deep plowing). The loss of organic matter results in deteriorated soil physical properties (e.g. weak structure, slow water infiltration, low water holding capacity and high bulk density), reduced nutrient availability, increased water run-off and poor aeration in the root zone. Consequently, yield is reduced and erosion susceptibility is increased. However, because it is difficult to isolate the effect of organic matter loss on productivity from that of the other forms of soil degradation (since the processes are interrelated), it is also usually difficult to isolate the associated economic costs.

Amelioration can be achieved by replacing organic matter at a rate equal to or higher than the rate at which it is being removed. Practices such as green manuring and composting are usually beneficial. In Eastern and Central Canada, it is believed that the loss of organic matter from agricultural lands could be estimated at 30-40%[24] of their original levels over the last 50 years (Agriculture Canada, 1985; Mehuys, 1984).

2.3.1.1.5. Secondary Soil Salinization

Secondary soil salinization[25] is defined as the increase in soil salinity levels due to agricultural practices or increased surface run-off. It results from the addition, re-distribution and concentration of soluble salts (from fertilizers) by ground or surface waters (Anderson and Knapik, 1984). Additionally some cultural practices such as summer-fallowing (which is commonly practised in Central Canada) can be a major contributing factor (Agriculture Canada, 1985). As a result, salts become more concentrated at or near the soil surface.

Increased soil salinity can cause reductions in yield depending on the levels of crop sensitivity. Salinity can also affect structures and roads (Anderson and Knapik, 1984).

---

[23] Intensive cultivation decreases organic matter level by accelerating decomposition processes (Mehuys, 1984).

[24] This estimate is based on plots of land with an average organic matter content that has not suffered from conventional agricultural impacts. Mehuys (1984) used the term "virgin forest" to explain this type of land.

2.3.1.1.6. Off-Farm Impacts

The off-farm impacts of soil degradation (mainly from erosion) may be as significant and as costly as on-farm impacts in many countries, including Canada. Eroded soils, along with their organic matter and agricultural chemicals, are carried by wind and water to adjacent fields contributing to the formation of gullies, ditch-bank collapse and filling of drainage ditches. In addition, the transported sediments may enter water bodies causing increased sedimentation of rivers, reservoirs and clogging of waterways and drains (thus requiring increased costs for maintenance and repair).

Some of the eroded matter, often-carrying plant nutrients and pesticide residues, may contribute to eutrophication, causing negative impacts on fish populations, habitat and recreational uses. Chemicals can also reach ground water through run-off and leaching. This problem becomes particularly acute when chemically-polluted water is used for irrigation or human consumption.

2.3.2. Water Pollution

Agriculture is believed to be among the largest non-point sources of surface water pollution in many countries in the world. For example, in the USA, it is reported to be responsible for half of all water pollution (US Environmental Protection Agency, 1991). The main agricultural pollutants include eroded cropland sediments (soil, plant debris, organic matter), irrigation run-off, salts, animal wastes, bacteria from organic matter and chemicals such as fertilizers and pesticides, all of which, have resulted in reduced water quality for irrigation, industrial and domestic uses.

Eroded soil sediments in water streams increase turbidity and decrease light transmission, thus inhibiting the growth of aquatic vegetation and the dependent species. Sediments also fill up reservoirs and reduce their recreational and navigational uses. Drinking water obtained from such sources requires more treatment[26] to remove pesticides before it can be consumed (US National Research Council, 1989).

---

[25] Primary salinization refers to naturally-occurring high salinity soils.

[26] Clark (1979) reported that the costs of potable water treatment doubles or triples when pesticides are present.

Agricultural chemicals, such as fertilizers and pesticides, are carried by eroded soil and water run-off to water streams. The degree of chemical contamination of surface water bodies depends on the rate, method and timing of application, type of chemical, soil characteristics, climate, and the proximity of fields to water sources (wells, rivers and others). This problem may sometimes be quite significant, for example, in the USA it is estimated that 50-70% of the nutrients (mainly nitrogen and phosphorus) reaching surface water bodies originate from agricultural lands (Phipps and Crosson, 1986). These result in serious problems and impose a high cost to the society.

Chemicals may also leach into underground aquifers. An increasing number of agricultural contaminants, including pesticides and nitrates, have been found in groundwater in the US and Canada (National Research Council, 1986, 1989; Environment Canada, 1999). Most nitrate contamination of ground water is believed to originate from the use of soluble nitrogen fertilizers (Nielson and Lee, 1987). Most synthetic pesticide residues are poisonous and some may have carcinogenic effects on human, other mammals and fish. This may lead to serious impacts on human health, as ground water is an important source of drinking water for many countries including Canada[27]. Health impacts are discussed in more detail in section 2.4.2.

In general, the amount of eroded fertilizers is larger than that of pesticides because the amount of fertilizers applied is usually much larger. Environment Quebec (1988) estimates that about 1-5% of the quantity[28] of applied pesticides reach water bodies. The impacts of fertilizers and pesticides are reviewed in the next two subsections.

2.3.2.1. <u>Impacts of Fertilizers</u>

Although several plant nutrients contribute to water pollution, nitrogen (as nitrates from fertilizers and animal wastes) and phosphorus are the major contaminants. Nitrates increase salinity and lower water quality for drinking and agricultural uses. In addition, these nutrients cause at least two more problems: 1) eutrophication that results in a

[27] Statistics Canada (1991) reported that about a quarter of Canada's population depend on ground water for domestic use. Similarly, the agricultural sector in Quebec withdrew 29% of its needs from ground water supplies in 1986.

[28] Environment Quebec (1999) estimated that about 3,381 tonnes (active ingredients) of pesticides were introduced into the environment in 1997, of which the agricultural sector was responsible for 80.8% or 2,732 tonnes.

reduction of fish catch and recreational activities; and 2) increased health risks to humans and livestock as a result of the consumption of contaminated water.

Eutrophication is the process leading to the depletion of oxygen from water due to the excessive growth (and decay) of algae as a result of high levels of nitrogen and phosphorus present in water. Some of this algae, the blue-green (cyanobacteria), releases toxins that render the water poisonous. Furthermore, algae produce bad odours and clogs inlets of water treatment plants. Health impacts of fertilizers are discussed in more detail in Section 2.4.2.

2.3.2.2. Impacts of Pesticides

The impacts of pesticide on water bodies depend on the pesticide characteristics (i.e. persistence, mobility, degradation, solubility, volatilisation and synergistic effect), its rate of application, soil type, plant uptake, land topography and intensity of rainfall and irrigation. Impacts can be divided into two main categories: those on the aquatic ecosystem and those on humans.

Because many pesticides degrade slowly, they persist in water bodies and can cause impairments to the water uses, and damage to the neighbouring fauna and flora populations. Many beneficial and desirable organism populations can be adversely affected (reduced or suffer behavioural and structural changes), with consequential impacts on higher organisms up the food chain, including humans. Health impacts of pesticides are discussed in more detail in section 2.4.2.

2.4. Social and Health Impacts

Many farmers in industrialised countries, including Canada, claim that modern conventional production practices have contributed to many negative social impacts such as reduced on-farm employment opportunities, increased health risks from the use of petroleum-based chemicals and reduction in their quality of life due to the deterioration of rural communities, among others. It is also felt that new advances in technology especially in the science of genetics have resulted in food of lower quality (Hill and McRae, 1992). While the extent of these issues is debatable, many scientists have raised concerns about these issues. In this study, the analysis of social impacts will be limited to two main issues: on-farm employment and health issues.

2.4.1. On-Farm Employment

The high dependency of modern agricultural techniques on mechanisation have favoured larger farm operations on the premise of economies of scale, resulting in the gradual disappearance of small farms as they become less cost competitive. This trend has also been witnessed in other sectors of the agri-food sector in countries like Canada and the US, such as food processing, marketing and in the input markets, which have become more concentrated (MacRae, 1991; Batie and Taylor, 1989). While such actions were seen by large firms as necessary to control the market and reduce risk (MacRae, 1991), others have seen it as means to increase profitability by raising input costs for farmers and retail prices for consumers (Teece, 1988). Such oligopolistic and monopolistic activities may have contributed to the decrease in the overall employment in the agri-food sector (Francis, 1986). Additionally, increased reliance on (advanced) machinery has been seen by some as inevitable to reduce costs to counter the vigorously competitive markets caused by increased globalisation effects, which have resulted from weakened trade barriers and reduced transportation costs (Midmore and Whittaker, 2000).

While modern machinery may have been more productive and helped reduce operating costs, the lesser reliance on labour has resulted in lesser on-farm employment opportunities and may have weakened the rural economic base and contributed to increased urban migration. This is amplified by the fact that rural labour markets seem to be somewhat inflexible in the short term.

The importance of non-conventional agricultural practices such as organic production, which is more labour-intensive, lies in the potential to provide more on and related off-farm job opportunities than conventional agriculture (Jansen, 2000; Lampkin, 1990). As such, this may have several positive social implications, such as reducing migration rates, preserving small farms and farming communities, raising income levels of farm workers and consequently, improving living standards. These issues may be more important, from a social perspective, to many rural communities (and perhaps to policy makers), than economic outcome figures alone, which may suffer due to higher costs of labour inputs. However, this issue remains highly contentious.

2.4.2. Human Health Issues

An extensive literature exists on issues relating health concerns to conventional agricultural practices. This is divided into three main categories: 1) on-farm mechanical accidents as a result of machinery use; 2) impacts to farm workers from handling and spraying of agricultural chemicals and from the contact with chemically contaminated crops during harvesting; and 3) impacts to consumers (including farmers) from the consumption of chemically contaminated produce and water. This study will only discuss the latter two issues.

It is well known that pesticides have a toxic impact on insects, birds, livestock, wildlife, plants and humans. While all impacts are considered important, this study will only examine the effects on humans.

Impacts on humans may occur due to the consumption of pesticide-contaminated food and water[29] (ingestion), contact with skin and other body organs such as eyes or lips (dermal exposure), or from the inhalation of chemical fumes. The latter two impacts are mostly unintentional resulting from drift, improper management, handling and inadequate precautionary measures during chemical spraying. Short-term acute[30] consequences vary from light irritation and respiratory diseases to severe poisoning and even death in some cases. The long-term chronic consequences include impacts on human physiology, growth and behaviour. These impacts are less understood but are suspected to be as important and significant as the short-run problems. Of the chronic impacts, cancer is of most concern considering the high incidence of this disease, on a global level, its often fatal outcome and the overall cost to society (Extoxnet, 1993). Even though scientists do not yet understand exactly how cancer occurs (Extoxnet, 1993), a number of epidemiological studies link increased risks of certain cancers to farmers to their exposure to farm chemicals (Simpson *et al.*, 1991). Pimentel *et al.* (1992) believed that less than 1% of the US total human cancer cases might be linked to pesticides.

---

29 According to Dr. Gilles Emond (19??) of Quebec's Department of Agriculture, consumers eat, among other toxic products, an average of 40 mg of pesticides per year. This amount is not that large compared to other poisonous substances that may exist in human diet, however, it is believed to increase the probability of sickness.

30 Acute effects occur within minutes, hours or days while chronic effects appear only after weeks, months or years (Extoxnet, 1993C).

In general, pesticide toxicity depends on several factors such as chemical group, form, method of absorption or exposition, human sensitivity, dose (amount absorbed & time course of exposure), persistence in food, etc. However, it is believed that most on-farm pesticide accidents are due to mis-handling and improper use (Environment Quebec, 1989).

It should be noted that an increasing number of regulations have been set in the USA and Canada to minimise risks of pesticide-related incidents and to reduce population exposure to health-hazardous chemicals, through extensive testing, chemical labelling, and education.

As for fertilizers, two main problems have been associated with relatively high nitrogen levels in drinking water: stomach cancer and methaemoglobinaemia (Marks and Ward, 1993).

Methaemoglobinaemia, an infrequently occurring disease, is caused by oxygen starvation in infants who are less than one year old and in young ruminant animals. This disease occurs when nitrate-nitrogen levels exceed 10 mg/liter of drinking water. Stomach cancer, on the other hand, is believed to result from the activity of the body's bacteria that transform nitrates to a carcinogenic compound (nitrosamines)[31] (Nielsen and Lee, 1987). Supporting this view, the National Research Council (1977), noted that a number of epidemiological studies have found a correlation between incidence of stomach cancer and high concentrations of nitrates in drinking water. Additionally, nitrates blend with chlorine in drinking water to form chloramine, which reduces the chlorine bactericidal effect (Environment Quebec, 1988).

In order to avoid adverse potential health effects, the European Community and the World Health Organization (WHO) have recommended against exceeding a maximum level of 50 mg/litre of nitrates in water used for drinking. In Canada, the maximum

[31] Nitrates will be reduced, under certain conditions, to nitrites in the gastrointestinal tract. Nitrites will react with secondary amines (present in foods) to form nitorgen-nitroso compounds that may have carcinogenic effects (Rajagopal and Tobin, 1989).

allowable nitrate levels are lower (40 mg/litre of nitrates or 10 mg/litre of nitrates-nitrogen).

The above discussion was intended to briefly show some of the health hazards from the use of synthetic agricultural chemicals.

2.5. Impacts of Organic Agriculture: A Brief Literature Review

Information regarding the environmental impacts of organic production systems is sparse although there seems to be a recently increased interest in this field. However, scientists have often debated the key aspects of performance to use in the comparison of different systems (van Mansvelt and van der Lubbe, 1999; Rigby and Caceres, 2001) and the methodologies to be used (Bockstaller *et al.*, 1997, Andreoli *et al.*, 1999; Girardin *et al.*, 2000), but most of them have considered impacts on soil, water, in addition to financial and human health aspects.

Many studies in the literature recognize that organic systems tend to be less harmful to the environment than the conventional ones, both on a farm or larger scales (e.g. Stolze *et al.*, 2000), but the degree of improvement varies between studies. There are, however, very few that show contradictory conclusions in key environmental impacts. Stolze *et al.* (2000) conducted a thorough comparison of organic systems with conventional ones using a review of literature, field experiments and questionnaires to experts in various European countries. The study focused on four indicators: ecosystem (floral, faunal and habitat diversity and landscape), natural resources (soil health, quality of ground and surface water and air quality), farm input and output (nutrient use, energy use and water use), and health and welfare (animal welfare and health and quality of produced food). The authors concluded that organic farming had less detrimental effects on the environment and resource use than conventional farming systems.

Some scientists (Pretty, 1995; Kirchmann and Thorvaldsson, 2000) reported that organic production may not automatically reduce its impact on the environment, but in fact, may have similar negative environmental effects (to conventional systems) such as leaching of nitrates from fields under legume (green manuring), volatilization of ammonia from livestock waste, accumulation of heavy metals in soils (following the application of Bordeaux mixture or raw phosphorus, for example) and soil compaction from the use of heavy machinery. However, most of the studies reviewed conclude that the key factor that will make the difference in reducing the negative impacts is the farmer's management skills. For example, if the nutrient supply is in synchrony with the plant demand then leaching of nutrients is minimized (Myers *et al.*, 1997), or if the farmer makes less use of heavy machinery and more use of improved crop rotations, this will cause less soil compaction etc.

Conacher and Conacher (1998) believe that organic farming can provide solutions to many environmental problems in Australia by promoting reductions in soil erosion and run-off, and decreasing the salinity of soil and water. Similar results were reached by Christensen and Johnston (1997) in the UK. Stolze *et al.* (2000) used a qualitative approach to analyze the results of previous studies. The authors addressed the impacts under seven headings (ecosystem, soil, ground and surface water, climate and air, farm input and output, animal health and welfare, and quality of food produced). They concluded that organic farming in general tended to perform better than conventional farming in many environmental aspects. These conclusions were confirmed by Cobb *et al.* (1999), the Danish Bichel Committee (DEPA, 1999), Hansen *et al.* (2001), Rigby and Caceres (2001) and others. The Bichel Committee employed 44 experts in various disciplines to assess a total conversion to organic farming in Denmark between 1998 and 1999. Hansen *et al.* (2001) used a driving-force-state-response (DSR) framework, which was developed by the OECD (OECD, 1997; Stolze *et al.*, 2000), to attempt to ensure a consistency between environmental and agricultural policies (Hansen *et al.*, 2001). This framework incorporates the causes of environmental change (called driving forces), which can be environmental, economic and social, and relates them to changes in the state of environment (including ecosystem, health and welfare) and to actions or reactions of groups in society (farmers, consumers, agri-food industry, authorities etc). It is also believed that increased requirements for labour in organic production will result in increased rural employment opportunities in both casual and full time jobs (Jansen, 2000; Lampkin, 1990, Offermann and Nieberg, 2000; Padel and Zerger, 1994), and consequently higher returns to family and hired labour (Jansen, 2000; Padel and Zerger, 1994).

While other farm-level studies exist, there remains a conviction that more research into the effects of various low input systems on different aspects of the environment as well as on society is needed.

In general, many positive impacts are expected from a wider adoption of organic systems on a country or even a global level especially as far as conservation of natural resources (i.e. less soil erosion, water pollution, energy consumption etc) is concerned, but there are also concerns about some negative impacts. Madden (1996) fears that the globalization of trade and the establishment of international certification standards, will facilitate the entry of huge multinational organizations into the sector and this may have an adverse effect on family farms, rural communities and food security, and therefore may negatively affect or reduce the contribution of organic systems to sustainability. Other scientists (Welch and Graham, 1999; Stanton *et al.*, 2001) believe that organic agriculture (among other low input farming systems) may not be able to produce sufficient food as the world population is expected to increase by two billion by 2030. A survey of horticultural producers by the University of Manchester, UK, in 1996 showed that only 13% of the interviewed conventional producers believed that organic farming methods were capable of producing sufficient food for the increasing population in comparison to 73% of the organic producers (Tisdell, 1996). The issue becomes more critical in developing countries, which are facing increased economic pressures and where short run solutions often come at the expense of natural resource preservation. This view is countered by optimists who believe that continuously improving technologies and further research will help make low input systems as productive as the current conventional ones.

CHAPTER 3

REVIEW OF LITERATURE I:
CBA and its Application to Natural Resources

3.1. Introduction

The main difficulty in extending[32] traditional CBA lies in identifying and/or applying the appropriate physical and monetary valuation techniques for relevant social and environmental impacts. A discussion of such methodologies and a revision of previous studies that measure the extent of soil and water degradation caused by conventional agricultural practices in Quebec, are presented in this chapter. The need for a change in the conventional economic paradigm is briefly discussed along with an examination of some of the advances made in the direction of extending the traditional CBA.

3.2. Environmental Accounting & Criticisms of CBA

Criticisms of conventional CBA as a project appraisal tool fall under the broader category of complaints against the current accounting system when dealing with natural capital resources. The need for improved environmental accounting has been discussed and undertaken by many economists[33] and organizations in several countries around the world.

Work has mainly focused on broadening the term capital to include natural (and not only human-made) capital (Costanza, 1991; Daly, 1994) and in redefining the way in which natural capital consumption has been handled in the accounting process. These efforts have been manifested in at least three directions: 1) adjusting the System of National Accounts (SNA); 2) the calculation of international balance of payments; and 3) altering the way in which appraisal of projects that deplete natural capital is done (Daly, 1994; Pearce, 1989), including the usage of "correct" prices of natural resources.

The idea was to distinguish true income generation from the depletion of capital assets by resource degradation. A true or a sustainable income is thought of as the maximum amount

[32] That is, in the direction of a more environmentally sensitive analysis.
[33] Such as Y. Ahmad (1989), E. Lutz and H. Peskin (1993), R. Repetto (1991) and others.

of a resource that can be consumed in the present without reducing the amount of possible consumption in a future period (Daly, 1989; El Serafy *et al.*, 1989; Schumacher, 1973). The development in environmental accounting requires the comprehensive incorporation of environmental impacts such as protection costs, the costs of natural resource degradation etc, into the system of national accounts to allow the assessment of trade-offs between the benefits and dis-benefits of production and consumption activities (Bailey *et al.*, 1999), This process is still being worked on in many countries (Peskin and Lutz, 1993). Examples include the Norwegian system of resource accounting (Alfsen *et al.*, 1987) and the French patrimony accounts (Theys, 1989). Further discussion of these concepts is beyond the scope of this research. Additional information on this topic can be found in Ahmad *et al.* (1989) and Lutz (1993).

In evaluating projects that deplete natural capital, it becomes important to fully account for all associated costs (and benefits), otherwise resource depleting projects will have inflated net benefits, and this will create a bias toward such projects (Daly, 1994; El Serafy, 1989). Correcting for this type of bias will be the first step toward a policy of sustainable development (Daly, 1994).

Of the project appraisal tools, CBA has remained one of the most widely solicited and used techniques by policy makers in both developing and developed countries. Discontent with CBA in resource-related project appraisal has led economists to consider using other appraisal tools such as Cost-Effectiveness Analysis (CEA), Environmental Impact Assessment (EIA), and Multi-Criteria Analysis (MCA)[34] (Hanley and Spash, 1993; van Pelt, 1993). These techniques have an advantage over CBA, as they facilitate the comparison of projects using qualitative data if the quantitative data is not available (i.e. unlike CBA, the techniques do not require the full monetarisation of effects). Nonetheless, due to CBA's popularity, responses to the discontent have resulted in developments that focused on widening the scope and objectives of conventional CBA to accommodate sustainability principles while the other techniques have been used as complementary

[34] EIA mainly involves the identification and physical quantification of the environmental consequences of projects. CEA looks at the cheapest way to reach the objects, i.e. consider costs but not benefits.

appraisal tools (van Pelt, 1993). Suggestions for the development of conventional CBA to better deal with the issue of sustainable development have so far focused on the following four aspects:

1. The economic paradigm embedded in CBA
2. The objectives of analysis
3. The discounting factor
4. The framework (scope) of analysis

These will be explained in more details, as follows:

3.2.1. Changing the Conventional Economic Paradigm Embedded in CBA

Many researchers have expressed the view that the present system and discipline of economics is not capable of fully recognising the values of sustainable development[35] (Henderson, 1981; Ekins, 1986). This discontent has given rise to various new directions in economics. Examples would include Evolutionary Economics (Boulding, 1981), Ecological Economics (Costanza, 1989), Environmental Economics (El-Hannawi, 1982; Soderbaum, 1990), and the attempts by several developed countries (including Canada), to include environmental accounting within the System of National Accounts (SNA)[36]. Midmore and Whittaker (2000) argue that sometimes, the rationale underlying economic techniques is at fault rather than the techniques themselves. In the case of agriculture, economists' emphasis on valuation has led to an emphasis on the effects on market equilibrium and the price system. The latter issue may have resulted in additional negative environmental impacts and less sustainable usage of (non-renewable) resources[37] with the wide effects of

[35] Markandya (1994) has noted that although there was no agreed upon operational definition of sustainable development, three main working rules/policies were proposed to act as guidelines for policy and project planning (including environmental management): 1) Equity in the distribution of benefits intra and inter-generationally; 2) Ecosystem resilience, the ability of the system to maintain its equilibrium against environmental fluctuations; and 3) Efficiency in the use of resources, which could be achieved by supportive policies and allocative mechanisms. Angelson and Sumaila (1997) believed it encompasses two main concepts: non-declining welfare and constant natural capital over time.

[36] Another similar concept, termed the System of Integrated and Economic Accounting (SEEA), was recently developed by the United Nations Statistical Office and the World Bank (Rao, 2000).

[37] The price system often does not give sufficient feedback on the social and ecological parameters.

globalisation[38], which have put increasing pressures on the prices of agricultural goods, and which increased the levels of competition in the market.

Although economists have acknowledged the shortcomings of neoclassical economics, the trend has been to work within the neoclassical framework due to the attractiveness of some of its features[39], and to overcome the deficiencies with adjustments rather than using alternative paradigms (Randall, 1987; Tietenberg, 1992; Midmore and Whittaker, 2000). Some of the needed adjustments are discussed in the following subsections.

3.2.2. Changing the Objectives of the Analysis

The strong emphasis on economic efficiency objectives as the sole criteria in traditional project appraisal analysis may have led to resource degradation in many cases. To counter this and to help reduce the risk of such effects, some economists (van Pelt, 1993; von Amsberg, 1993) have suggested the addition of a sustainability objective that is based on sustainable ecological, social and political criteria. The ecological criteria should be predefined in terms of: 1) specifying the environmental parameters in question and level of aggregation; 2) definition of the desired states of the environment and threshold levels of parameters; 3) defining acceptable levels of risk, and other issues such as the spatial level and the time path of analysis (van Pelt, 1993). Therefore, projects that do not meet the sustainability objective will not be implemented even though they may be economically efficient. These issues are not always easy to define because of the complexity of environmental and ecological issues. Besides ecological issues, the sustainability objective incorporates also political and social dimensions.

The political process has to decide on the following questions: 1) how are trade-offs between increased income or economic efficiency in general, and environmental degradation or equity treated? The same question may apply to trade-offs between the future and current generations' needs, and between the quality of resources and economic

[38] Globalization has contributed to decreasing transport costs and weakened trade barriers, which may have pushed to increased industrialization of agricultural processes to produce competitively-priced goods. (Midmore and Whittaker, 2000).

[39] Features such as a) emphasis on price signals, b) clarity of arguments and c) use of elegant models etc.

and social welfare (Pearce *et al.*, 1990); and 2) how does the government view its responsibility to future generations? (van Pelt, 1993; Barbier *et al.*, 1990). These issues often involve value judgements that are case specific, and depend on the prevailing societal ethics and values, property rights and priorities or objectives of the political system.

Other economists (e.g. Pearce, Markandya) have utilized the concept of a sustainability constraint. Such a constraint would help to restrict economic activities that reduce capital (and environmental) resources (in general, or below a certain critical minimum threshold), and which may lower the welfare of future generations. Two positions arise from the application of such a constraint: a weak and a strong sustainability criteria. The weak criterion is based on the works of Robert Solow and John Hartwick, and is sometimes referred to as the "Hartwick Rule" or the "Perfect Substitutability paradigm". This constraint calls for keeping the total capital intact, i.e. the aggregate value of natural capital and man-made capital to be at least constant[40]. With this constraint, man-made capital and natural capital[41] are seen as potential substitutes for each other both in production and utility functions (Neumayer, 1999). Therefore, natural capital can be depleted as long as enough man-made capital is produced in exchange, and regardless of the amount of pollution generated by the current generation in the process. This could also imply that reinvestment of the total rent from exhaustible resource exploitation will secure a constant stream of consumption over time (Barbier *et al.*, 1990).

The weak sustainability criterion assumes that a near perfect substitution can be made between various forms of capital, which may not always hold true (Neumayer, 1999). Pearce *et al.* (1988) believed that man-made capital and natural capital can be considered as complements in developing countries and trade-offs in more developed countries. Humans are often incapable of replacing natural resources (van Pelt, 1993) or providing alternatives

[40] There is a debate on whether the term "constant" refers to physical capital stock or economic value of that stock (Barbier *et al.*, 1990).

[41] Natural capital consists of natural and environmental resources, while man-made capital (also sometimes called reproducible capital) consists of physical, human and social capital (Dasgupta and Maler, 1990).

with comparable values. This assumption renders the criterion even weaker in cases where projects lead to irreversible effects or involve the depletion of non-renewable resources[42].

The strong sustainability criterion/paradigm was mainly developed by Herman Daly and Robert Constanza. It calls for keeping the value of the total capital and the value of the natural capital (or some subset of natural capital) at least constant. This paradigm is based on the assumption that natural and human-made capitals are thought to be complementary to each other. Barbier (1987) and Pearce (1987) noted that, in natural resources, this should apply to each type of environmental capital separately[43]. This criterion presupposes a rate of natural resource use that is below its regenerative rate (maximum sustainable yield), and environmental wastes to be below the environment's assimilative capacity (Angelson and Sumaila, 1997). It may also imply that non-renewable resources should not be used. This last view is often difficult, if not impossible, to apply, especially in developing countries, given the current rates of population increase and the pressures for development[44]. Other scientists (e.g Tisdell, 1996) have used the somewhat similar concept of "safe minimum standard". This is a threshold level after which, a certain resource like soil, for example, may face irreversible degradation or become reversible only at very high costs. However, methods to determine the threshold are often contentious.

While it may be impractical to require that no project should contribute to environmental degradation, it may be acceptable for a portfolio of projects to have a positive summation of damages over each period of time (Barbier *et al.*, 1990; Markandya, 1998). In this case, it may be accepted that some projects negatively affect the environment as long as the overall impact of the portfolio of projects has a compensatory effect to restore previous conditions, or offer a similar resource alternative (Markandya, 1998). This also implies that the aggregate total net value of a portfolio is kept above or equal to zero.

---

[42] Here, the values of costs and benefits should be adjusted to include the value of forgone preservation benefits or, again, to include the costs of a compensatory project that offers a similar substitute or partially ameliorates environmental degradation, if ever possible.

[43] There are many versions of a strong sustainability, some of which, allow the aggregation of some capital types, while others require the maintenance of a critical minimum standard of some natural capital.

[44] Angelson and Sumaila (1997) argued that the regenerative capacity of natural resources is not static and so is the waste assimilative capacity of the environment.

Pearce *et al.* (1990) called such behavior "compensating projects" that should be implemented to "create" a sufficient stock to compensate for unsustainable resource use in the original project. However, compensatory projects may have to be allowed even if their net economic feasibility (e.g. NPV) were negative[45] (Barbier *et al.*, 1990). The concept of a compensatory project can be useful only if natural capital depreciation can be properly measured (Tisdell, 1991), and if the levels for the adequate maintenance of natural resources are well defined (Weiss, 1994). The approach takes an optimistic view of man's ability to create natural resources (Van Pelt, 1993). There may also be other difficulties to operationalize this concept since it may be difficult to find a common compensating solution for a portfolio composed of different projects with different effects, especially where the decisions on projects are taken sequentially (Weiss, 1994). Additionally, there may be a conflict in determining project administration and payment schemes for the project. Still the concept of a compensating project offers a good theoretical solution, which needs to be operationally well defined. This is often case-specific.

It should be noted that this criterion with its compensation argument is in accordance with the theory of the Pareto-Criterion (PC), which is embedded in the spirit of CBA. The PC implies that beneficiaries from a project should compensate losers, and therefore, hypothetically all parties are made better off.

In summary, it is believed that the sustainability objective and constraints may help to insure that, in implementing a project, the overall wellbeing is maximized without reducing the welfare of future generations below that of the current generations. In reality, the operationalisation of the sustainability objective is difficult as it entails monitoring, governing the use, replacement and repair of current capital and natural stocks. It is argued that little has been done in this area to date (Pearce, 1991; Munasinghe and Lutz, 1993; von Amsberg).

3.2.3. Appropriate Discounting

Discounting is the process by which future streams of costs and benefits are converted into a common temporal unit (present values) to facilitate the aggregation of effects that are spread over time. This is done using the following formula:

$$PV = \sum_{t=1}^{n} FV_t / (1+i)^t \qquad \textbf{Equation 3.1}$$

Where

PV = Present value of costs/benefits
FV = Future value of a cost/benefit
i = Discount rate
t = Period

Discounting results in lower numerical values (and less weight) for future benefits and costs as compared to present ones. The higher the discount rate, the smaller becomes the future discounted benefits and costs, and, therefore, projects with near-term benefits and far-term costs are favoured.

Two arguments have been used to justify the use of a positive discount rate: 1) Positive rate of time preference; since individuals are impatient and prefer to consume their benefits today rather than in the future, and therefore, want to be compensated for their patience; and 2) marginal productivity of capital (or capital's opportunity cost). This latter point suggests that since capitals (or resources) are productive, they should not be left unused at present because they can be invested and their value will increase in future (Pearce and Turner, 1990).

The choice of the discount rate is an important issue in project evaluation and can have major implications for policy. The discount rate influences the desirability of projects, the rate of resource use and inter-generational equity - the distribution of benefits and costs among generations (Tietenberg, 1988).

[45] This will lower the overall net economic benefits of the portfolio.

Traditionally, economists have used the long-term interest rates on government bonds, adjusted by a risk premium set by the analyst, depending on the project (Tietenberg, 1988). However, some economists (e.g. Pearce and Warford, 1993; Ray, 1984) believe that market interest rates are socially incorrect when it comes to evaluating public investments including projects involving natural resources. This is based on the following arguments:

The market discount rate is determined by present markets and considers the current generation's time preferences and capital productivity and not future generations' preferences. However, as the activities of the present generation affect subsequent generations, the rights and interests of future generations may not be (properly) accounted for at (present) market-determined discount rates, especially since the discounting process itself tends to favour projects with near-term benefits and future costs. This can encourage projects with earlier depletion of non-renewable natural resources. In addition, the market discount rate accounts mainly for the interests of private individuals, which may not adequately accommodate society's interests, whether present or future generations. This point is especially true in the absence of any assurance for individuals that if they behave in an environmentally conservative manner, other members of society will do the same.

The issue becomes more critical in public investments since governments may seek the attainment of additional goals besides narrow economic efficiency. In this case, the use of a more socially favourable discount rate, one that is lower than the market-generated estimates, is justified (Randall, 1987). Such a social rate will reflect the opportunity cost of capital from a social perspective.

In projects involving natural resources with potentially negative environmental impacts, the choice of an appropriate discount rate becomes a crucial aspect when sustainability is a policy objective. Different discount rates imply different weightings of the interests of future generations and, consequently, affect the distribution of resource benefits and costs (pollution and wastes) across generations.

High discount rates may favour projects with near-term benefits and far-term costs[46]. This will shift the cost burdens[47] to later generations. At the same time, high rates may discourage additional investments in new (or existing) projects[48] but encourage savings, which in turn will affect the rate of economic growth and wealth of future generations[49]. In addition, several environmentally desirable projects may be shown to be economically unprofitable at high rates (thus opposing the sustainable development values as proposed by Markandya, 1994). Low rates, on the other hand, may imply a better distribution of environmental costs and benefits among generations, and will better reflect environmental concerns and sustainability issues, since projects with benefits accruing farther in the future (in the long term) will be less dis-favoured (Lutz and Munasinghe, 1991).

However, the relationship between environmental deterioration and the discount rate is non-unique and is sometimes ambiguous. High discount rates, whether to account for market opportunity costs or uncertainties[50], may reduce the overall level of investment, including the demand for natural resources and the resulting pollution from projects. Similarly, the reverse may be true, and may lead to increased pressure on environmental resources. Additionally, if the discount rate is used as a rationing/selecting device for project investments, some environmental projects that have lower rates of return (compared to other development investments) will be dis-favoured. This is particularly true for developing countries. Still, much of the environmental literature argues against the use of high discount rates.

---

[46] Over projects with far-term benefits and near-term costs at the same discount rate.

[47] Future generations will bear disproportionate share of the costs.

[48] Markandya (1994) noted that the argument that a high discount rate may help to allocate scarce capital in capital-starved countries is not sufficient as there may exists other mechanism to do so.

[49] This argument depends on whether investments in projects are expected to generate higher returns than the accumulated interest. Therefore, high interest rates will affect investments and savings and, consequently, affect the total desired capital stock. The argument may be less valid if future generations are expected to be richer than the current one due to the effects of technological or other changes.

[50] When uncertainties are accounted for by raising interest rates, this implies that the uncertainty is expected to rise at an exponential rate over time. This is often an exaggeration of the situation.

While, mathematically, this could yield somehow similar results to using a lower discount rate, it avoids being accused of distorting resource allocation by using a lower than the market discount rate. These modifications could prove to be especially useful in cases involving irreversible damage. However, there may be a difficulty in estimating the values of i and g, which may be unstable with time (Hanley and Spash, 1993).

Some economists (Markandya and Pearce, 1991) believe that the use of a sustainability constraint (discussed under point 2 of this section), which does not depend on adjusting the discount rate, may offer a better solution, since there are no guarantees that a lower discount rate may not cause some serious resource degradation. This reasoning is particularly obvious for projects that cause irreversible damage or that involve the depletion of non-renewable resources[55]. However, the assumption of near perfect substitutability or compensation limits these ideas.

Along these lines of thinking, Norgaard (1991) suggests direct income transfers[56] to future generations to compensate for environmental degradation since manipulating discount rates may result in an inefficient use of capital[57]. This, in turn, will result in new levels of savings and investments. However, assuming that such policy is chosen now, it may be difficult to commit subsequent generations to maintain this policy as the future generations may have strong incentives/needs to increase their consumption at the expense of the following generation (Philibert, 1999). Additionally such a suggestion is also based on the near perfect substitutability assumption (between natural and other forms of capital), which may not be valid (Neumayer, 1999).

[54] Demand may increase because of more information and awareness to its scarcity and value, and because of increasing demand for environmental goods and services as incomes rise.

[55] Much of the criticisms against positive discounting originated from economists and environmentalists dealing with long lasting or irreversible effects such as climate change or the decommissioning of nuclear plants etc.

[56] This was also called an "environmental tax" by Weis (1994) or a "compensatory set-aside scheme" by Pearce *et al.* (1994).

[57] Low discount rates may encourage indiscriminately all sorts of investment programs, even non-environmentally related ones.

Other economists believe that the role of discount rate in treatment of environmental effects can be less problematic if better measurement and valuation of environmental impacts are made (Markandya and Pearce, 1988; Daly, 1989; van Pelt, 1990; Lutz and Munasinghe, 1994). Consequently, there will be a lower need for reductions in the rate (or even increases to accommodate environmental risk). Markandya and Pearce (1988) preferred the adjustment of costs and benefits to their certainty equivalents instead of adjusting the discount rate[52], when possible, as major uncertainties exist in estimating costs and benefits. This idea could be useful if probability distributions can be assigned to various outlays.

In the same context, there have been alternative measures used to insure sustainable use of resources by means other than directly adjusting the market discount rates. Using a market discount rate (r%) for analysing environmental projects, Krutilla and Fischer (1975) suggested the valuation of benefits and costs in a manner that reflects their changing values over time. Therefore, environmental benefits would be discounted at a rate equal to (r+i)%, with i representing an annual rate of decline in the value of benefits or a depreciation effect, since benefits (from a certain project) are expected to fall with time, especially with technological progress, which generates cheaper and more effective alternatives to the one already used. At the same time, costs of resources, or environmental costs, are expected to appreciate with time, at an annual increasing rate; g%, which is slightly lower than the discount rate. This is equivalent to using a overall discount rate of (r-g)% for the costs. This is because of the increasing relative scarcity (supply) of the resource and its consequent effect on prices[53], especially since demand will be increasing[54]. The idea of evaluating certain natural resources at a progressively higher value was also advocated by Philibert (1999) due to the increase in absolute rarity, and since such amenities can not be replaced by technological progress.

[52] Markandya (1994) noted that adjusting the discount rate is not an efficient procedure although it may help to protect the interests of future generations.

[53] According to the law of diminishing marginal utility, as resource declines, the remaining units become more valuable as consumers 's willingness to pay for it increases.

The idea of using low rates is not new. It was discussed by Pigou (1932) who believed that in order to protect the interests of future generations, governments, as trustees of future, should correct the bias favouring present generations and use a lower discount rate (than the market rate) in evaluating public investment projects, including ones with environmental components. However, there may be a difficulty in classifying projects that can benefit from the assessment at low rates, since many projects have an environmental effect, to a certain extent, and this may also pose some complications to the governments in fund allocation (Markandya, 1994).

In the United Kingdom, the Treasury guidelines recommend a (real) discount rate of 6% for public sector projects, but allow a lower rate for projects that have very long-term effects. A 3% discount rate, for example, is allowed for forestry projects (Markandya, 1998).

Most economists prefer to use a constant discount rate across the life of a project. While the use of multiple discount rates may offer better estimates, there are a lot of uncertainties about the appropriate future rate of return on capital. Weitzman (1998) suggested using certainty-equivalent social discount rates, but that is still difficult to estimate.

Weitzman (1994,1998) also questioned the exponential nature of discounting since it transforms "monumental events" that occur in the distant future to minor events. He suggests using a discount rate that is not only lower than the marginal return on private investment, but also one which is declining over time, since "greater economic activity typically results in disproportionately greater environmental degradation through pollution". This will allow a better evaluation of costs involved. Philibert (1999) also recommends the use of a declining discount rate as future slowing of economic growth may be inevitable due to the limitations of the planet. However, this point is uncertain due to the expected positive changes resulting from continuous advances in technology. Cropper *et al.* (1994) and Azfar (1999) believed that people generally discount the future at declining rates of interest (hyperbolic discounting)[51].

[51] Hyperbolic rate means that individuals discount the distant future at lower rates than they discount the near future.

Some environmentalists argued against the concept of discounting in the analysis of projects with environmental aspects, and especially for projects involving potentially exhaustible resources (Goodin, 1982 and Partiff, 1983)[58]. This, however, will create a lot of inefficiencies and distortions. Since a typical investment entails costs that are borne by the present generation and benefits that accrue to future generations, the future generations will receive benefits but will not incur the costs if discounting was not practised, while, at the same time, the current generation incur costs but do not receive the benefits[59]. Additionally, discounting acts as a device for rationing funds between public and private sectors, where the former could have over invested with the absence of discounting, leading to increased taxation, non-sustainable use of natural resources, and consequently high levels of environmental degradation. Markandya and Pearce (1988) argued that the rationale against discounting was not very convincing.

The above discussion reflects the importance of using an appropriate discount rate. There is no universally right rate for public projects. The rate varies based on the project/problem under consideration. In general, it is believed that using a lower discount rate (for projects with major environmental components)[60] may better protect the collective welfare of both present and future generations.

3.2.4. Widening the Framework of Analysis

In their traditional framework of analysis, neo-classical economists have been accused of focusing on immediate economic impacts and neglecting the environmental and social implications because they did not fit into their models (Henderson, 1981; Hall *et al.*, 1992). In addition, the analysis has often focused on the individual unit of analysis and not the overall society. These considerations are not conducive to sustainable decisions.

[58] In this case, the discount rate will influence the rate of extraction. Consequently, it will be optimal to deplete the resource if the discount rate exceeds the natural rate of resource regeneration plus the rate of change in its price (Markandya, 1994).

[59] The reverse could be true for a nuclear power plant, but only few public projects entail so much weight on future costs.

It is often believed that sustainable approaches to decision making are better reached by an institutional framework that is more holistic, inter-disciplinary, and value-conscious (Soderbaum, 1987, Aldy, 1998; Regmi and Weber, 2001). Checkland and Scholes (1990) called for systems thinking, which had become a pre-requisite for rural systems to develop in a sustainable fashion. Other economists have called for a full cost pricing strategy (e.g. Hufschmidt *et al.*, 1983 and Veeman, 1991), whereby negative externalities, such as the costs of environmental degradation and non-renewable resource consumption as well as other social costs are internalized, and are thus reflected in the price of goods produced (Henderson, 1981). Externalities are often described as a form of market failure[61]. When present, competitive markets do not yield (economic) efficiency[62] (Bowers, 1997) and market prices do not reflect the full costs and benefits to society (Kirkpatrick and Lee, 1997), partially because it does not provide sufficient feedback on social and ecological parameters (Midmore and Whittaker, 2000).

In support of this idea, Hufschmidt *et al.* (1983) believe that the effects of any development project on environmental quality and natural systems must become an essential part of project formulation and evaluation if protection is to be provided to the natural base that sustains human welfare. This change in analysis to include information on changes in all relevant components is a necessity if the results are to be consistent with sustainability (Midmore and Whittaker, 2000). In discussing this idea, MacNeill (1989) states "If we change the way decisions are made, we change the decisions that are made". Internalization of associated costs will also help to promote development activities that preserve the long run productivity of natural systems for sustained development and will minimize deterioration in environmental quality (Hufschmidt *et al.*, 1983). This is particularly

---

[60] A lower discount rate for all projects will encourage a larger total investment and this will increase pressure on natural resources and lead to higher levels of environmental degradation.

[61] An externality is defined as a benefit or a cost that is not considered by market buyers and sellers (Tucker, 2000). Other reasons for market failure include ill defined or absent property rights of resources, unpriced resources, unaccounted-for externalities, high transaction costs, market imperfections, uncertainty and irreversibility (Petry, 1995).

[62] One of the main reasons for this is that with externalities, gains from trade are not exhausted. Tucker (2000) attributed externalities to the divergence between social and private costs and benefits.

relevant to sustainable agriculture, where appropriate assessment of the agro-ecosystem's performance has to consider its socio-economic dimensions (Barbier *et al.*, 1990).

Although not guaranteed, efforts toward making decisions advocating sustainability can be better supported by incorporating the environmental and social impacts into the analysis. In the case of projects leading to irreversible damage, this can be reflected by adjusting costs to include all forgone benefits (Munasinghe and Lutz, 1993).

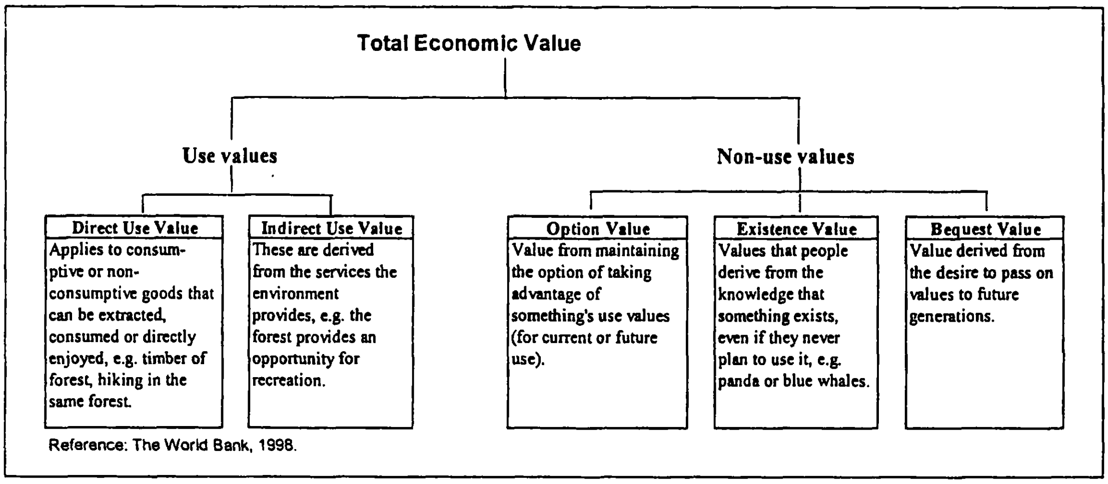
Combining economic findings with quantitative information on a project's physical and biological sustainability would facilitate the comparison of alternative projects or systems of production, and would give decision makers a more complete picture of the project's comparative economic benefits (Lockeretz, 1989). This will help acknowledge the important public benefits that practices such as organic farming may provide (MacRae, 1988; Lampkin, 1985).

It should be noted that there are several regulations that were introduced in the USA and the UK since the late 1980s that require the consideration of environmental costs and benefits for any proposed legislation. These were stipulated in the US Presidential Executive Order 12291 and in the UK's Ministry of Environment guidelines titled " Policy Appraisal and the Environment" (1991).

In addition to the inclusion of (all) relevant impacts, it is important that the monetary valuation process captures the full value of the natural resource/amenity. To do that, many economists (e.g. Dixon, 1994; Markandya, 1998; Turner *et al.*, 1993) have used the Total Economic Value (TEV) approach, whereby an environmental impact is disaggregated into several components/categories of value. The idea behind this approach is that any good or service is composed of many attributes, some of which is easier to measure or quantify than others (the World Bank, 1998).

The TEV approach divides the values into use and non-use values. In general, the former consists of direct (extractive) and indirect (non-extractive) use values, while the latter consists of option, existence and bequest values. A brief description of these values is made in Figure 3.1. More details can be found in Dixon *et al.* (1994).

Figure 3.1: The Components of Total Economic Value



However, quantifying and costing these impacts is not an easy step. Damage is often selective and unequally distributed in time and space and among societies (El Hannawi, 1982), and the understanding of the vulnerability and resilience of different ecosystems, and its ecological relationships (cause-effect), is far from complete, and often requires a good merging of social and natural science disciplines and appropriate tools (Murdoch and Clark, 1994; Andreoli *et al.*, 1999). This problem is also compounded by the lack of reliable data on ecosystems in many cases. Furthermore, even within the same society, individuals may have different sets of values and priorities. Nonetheless, economists have been developing approaches to incorporate monetary values of environmental amenities into the decision making framework over the last 30 years with considerable success (Veeman, 1991; Adamowicz, 1991; Bockstaller *et al.*, 1997; Van Mansvelt, 1997; Hansen *et al.*, 2000). The overriding research issue has been to find the most sensible ways of assigning value to natural resources and natural capital (King, 1994), and in many cases, to attempt to capture as much of the total value as possible. A list of potentially applicable valuation techniques to each category of value, as suggested by various economists, is shown in Figure 4.1. These will be discussed in the context of their use in the next chapter.

3.2.4.1. Extending the Framework: Applications to Agriculture

Previous studies on the integration of various impacts in the comparison of conventional to organic farming systems are sparse. Cobb *et al.* (1999) pursued this issue in relation to one case study, and looked at agronomic, ecological and financial factors using secondary sources. Agronomic factors consisted of nutrient flows and vegetation changes to field margins. Ecological aspects included butterfly and spider populations, soil erosion, energy usage, emissions of green house gasses and leaching of chemicals. The authors believed that gaps in data and mis-understanding of the many complex ecological relations between various variables have prevented them from reaching precise figures. However after assessing each variable separately, using mostly field experiments and some secondary data, they concluded that organic systems showed considerable differences in the overall environmental benefits and financial profitability when compared to conventional systems. The conclusions they reached were intended to support increased subsidies, incentives and other policies promoting sustainable agriculture.

Another related study was done by Bailey *et al.* (1999) to compare the financial performance and environmental benefits (or dis-benefits) of integrated farming systems with that of conventional in relation to a case-study farm that belongs to the LINK-Integrated Farming System experimental sites. The latter is a project to compare both farming systems over a five year rotational plan in six different agro-ecological zones around Great Britain (Ogilvy *et al.*, 1994). In addition to financial data, Bailey *et al.* (1999) evaluated the impacts on the environment based on its three main economic functions: First as a source of raw materials; second as a sink for waste assimilation; and third as a provider of environmental services. Indicators in the first category included soil quality, and specifically aspects of organic matter content, levels of acidity, levels of phosphorus, potassium and heavy metals, population of invertebrates, and in particular earthworm numbers and/or biomass since these contribute to soil fertility and structure improvement. For the second category, indicators included the impacts of nitrates leaching on surface and ground water. For the third category, the authors looked at bio-diversity impacts reflected by the number of invertebrates (beetles and spiders) caught by pitfall traps on the farm. Integrated systems were shown to have higher gross and net margins than conventional, lower usage rates of chemicals and nitrates (and therefore economic savings) and lower nitrate leaching (less treatment costs for drinking water). However, the authors found difficulties in ascribing a suitable estimate for the value of invertebrates as an indicator for biodiversity. However, after integrating the various effects, the authors ended with some counter-intuitive conclusions suggesting that some aspects of the two systems were statistically indifferent or even were better under the conventional system (e.g. earthworm numbers). The authors related that to the time lag between following certain conservative practices and the observation of environmental benefits. However, this may also be attributed to the difficulty in the physical estimation of impacts and to their choice of indicators, reflecting the complexity of the issues studied. Bailey *et al.* (1999) cautioned against drawing firm conclusions from their study or from adopting their figures as final. They believe that the main value of their study lies in exploring some methods of comparison between the two systems.

There exist many other studies that evaluate different environmental impacts of various agricultural systems including organic ones but the ones that attempt to have an integrative evaluation are rare. Examples of these include the work of Pimental *et al.* (1992), Pretty *et al.* (2000) in addition to the ones mentioned above. This is understandable given the multitude of variables and disciplines involved, high requirements for detailed data, difficulties in the physical and monetary evaluation of impacts and in the selection and/or development of appropriate techniques. Further research is this area seem to be of increasing interest in many countries (Andreoli and Tellarini, 2000).

Pretty *et al.* (2000) attempted to assess the negative external and health costs of agriculture in the UK. The authors relied on treatment or prevention costs and administration and monitoring costs for seven categories: damage to natural capital, i.e. water, soil, air, biodiversity and landscape, damage to human health, i.e. from pesticides, nitrates, micro-organisms and other disease agents. Relying on 17 datasets of a range agencies in the UK, the authors estimated the total costs to be £2343 million in 1996, which is equivalent to £208 per hectare of arable and permanent pasture. The authors felt that these figures underestimate the total damage due to the conservative assumptions they made and the limited number of variables they choose.

There are several studies that attempted to develop methods to facilitate the integration of various variables. One of these is the work of Bockstaller *et al.* (1997) who developed an "Agro-Eco" model for the evaluation of farming systems from environmental and agronomic perspectives. Their model consisted of a set of agro-ecological indicators that evaluate the degree of achievement of integrated arable farming system (IAFS) objectives using a qualitative scale ranging from 0 to 10. The IAFS objectives were discussed by El Titi (1993) and included the protection of the qualities of ground and surface water, soil, air, non-renewable resources, biodiversity and landscape. The authors felt that designing the scale in this manner was necessary to avoid the usage of physical measurements, which may be difficult to estimate by farmers since they may be data intensive and require some technical knowledge. Their model consisted of seven indicators, namely crop diversity, crop succession, pesticide, nitrogen and phosphorus fertilization, organic matter and irrigation. The evaluation of performance of each variable depended on either scientific knowledge or expert judgement (which is site-related). However, the evaluation of various indicators are not cumulative, since one unit has a different meaning in each indicator. This prevents the aggregation and integrative comparison of various systems. The authors seem to be assuming a strong sustainability constraint, which discourages compensation or substitution between various components of the model on the premise that it may be difficult to decide which variable is more important.

Nonetheless, Bockstaller *et al.* (1997) believe that their model will help farmers to assess their performance and adapt their practices to match the IAFS requirements. Additionally, the model may be used by decision-makers to monitor or evaluate their agro-environmental policies.

Girardin *et al.* (2000) expanded the Agro-Eco model by adding two additional indicators, crop covering and ecological structures and attempting to add another two, energy and soil management. The model was slightly modified to permit the evaluation of any of ten agricultural practices (e.g. pesticide management) on all environmental components, or the sensitivity of one environmental component (e.g. water, air etc) to all the farmer's practices on a given field. However, Girardin *et al.* (2000) were able to do an aggregation of the studied impacts using multi-criteria method of ranking to allocate weights for different factors. However, the authors felt that this model was still unable to compare various cropping systems but was capable of assessing the potential impacts of agricultural techniques on the environment. De Koeijer *et al.* (1995) used linear programming and multiple goal programming models to investigate exchanges between income and environmental pollution for mixed farming systems. The authors used only a few variables and initially assumed equal weights for various goals. Later they modified the weights to see how results would vary. Goal programming seemed to have a good potential in evaluating different farming systems once accurate relations can be estimated between farming practices and environmental impacts.

Some modeling equations such as EPIC, which enables the estimation of environmental impacts and economic returns was used by Kelly *et al.* (1996) to evaluate the performance of seven rotation plans and evaluate the economic-environmental tradeoffs. The model seemed to be useful as a decision tool in determining the optimal rotation to satisfy various environmental goals (e.g. least water pollution or soil erosion etc).

Van pelt (1993) has suggested using multi-criteria analysis (MCA) techniques, which permit the simultaneous consideration of multiple decision criteria, and could therefore offer solutions to the integration of multiple variables and objectives especially in the absence of quantitative data, since the techniques can generate useful results with qualitative data. MCA is an umbrella encompassing several techniques based on mathematical programming such as Goal Programming, Multi-objective Programming, Multi-criterion Simplex Method and others. The techniques allow the weighting of various variables to reflect the priorities of policy makers. More details about these techniques can be found in Nijkamp *et al.* (1990) and Petry (1990). Romero and Rehman (1987) reported that MCA techniques were used successfully in the management of natural resources such as in fisheries, agricultural land use, forestry planning and water resources.

Andreoli *et al.* (1999) and Andreoli and Tellarini (2000) used MCA techniques for the aggregation of impacts, with weights for various variables allocated subjectively. Values for different variables were transformed into utility equivalent, whether linear or otherwise with values (ranging from 0 to 1) assigned to different physical situations (e.g. 0 to severe erosion and 1 to no erosion etc.). Andreoli and Tellarini (2000) applied their methodology to a range of farms in Italy and concluded that mixed styles of farming including organic had a positive influence on landscape quality.

MCA has also been used to assess the relative sustainability of various production systems (Lampkin, 1998, Stolze *et al.*, 2000). This concept depends on proper definition of sustainability criteria and indicators for measurement as well as objective means to sum the various performance measures. Lampkin (1998) compared three livestock production methods in terms of five objectives: supply and quality of food and fiber, financial vaibaility, social and cultural identity of rural communities, conservation of natural resources and impacts on other ecosystems. Lampkin (1998) relied on a subjective scoring method to amalgamate the various performance measures. His study showed that the organic model was better when equal weights were allocated to the various objectives or when the environment had a higher weight. The author stressed the importance of developing an objective way to account for various objectives which would allow a better comparison of the systems' contribution to sustainability objectives. Stolze *et al.* (2000) attempted to evaluate the environmental and resource use effects on agricultural land area of organic relative to conventional farming in Europe using a qualitative MCA. The authors selected a group of indicators from the OECD set of environmental indicators for the agricultural sector related to organic farming. These included ecosystem, natural resources, farm input and output, and health and welfare. It is believed that that study is one of the most comprehensive studies to date on this issue. Stolze *et al.* (2000) relied on literature review, field experiments and questionnaires to experts in various European countries, to evaluate the parameters subjectively based on the authors' expert knowledge within each indicator, and then aggregated the indicators to a sustainability index using a qualitative scale, giving them equal weights within an MCA framework. The authors concluded that organic farming had less detrimental effects on the environment and resource use than conventional farming systems.

There has been other examples on the use of MCA to assess the relative sustainability of various systems. For example, Simonovic (2001), applied this technique to assess three water management schemes for ground water use in a water aquifer in Manitoba, Canada in terms of three critieria: risk, equity and reversibility. This shows that this concept can have wider applications. The author also suggested combining the results with other decision-making tools such as CBA and environmental assessment techniques.

There have been many other attempts to measure the relative sustainability of agricultural systems (e.g. Olson, 1998; Lefroy *et al.*, 2000; Nambiar *et al.*, 2001). Again, most of the studies relied on the development of a sustainability index that would facilitate the comparison between systems. For example, Nambiar *et al.* (2001) developed an agricultural sustainability index by combining a broad set of biophysical, chemcial, economic and social indicators. The compound indicator was the product of agricultural nutrient balance, crop yield, soil quality, agricultural management, agri-environmental quality, agricultural biodiversity, economic and social aspects of sustainable agriculture and agricultural net energy balance. The index showed promising results when used to compare relative sustainability of various agro-ecosystems over a nine-year period in the coastal regions of China.

However, most of the studies above have expressed concern regarding the lack of a commonly accepted and objective way for aggregating and scoring the various components (Lampkin, 1998; Stolze *et al.*, 2000; Nambiar, 2001 and Simonovic, 2001).

It should be noticed that work on the devlopment of sustainability indicators is still the subject of ongoing research by many governmental and non-governmental agencies. Some of these agencies include Environment Canada (Canadian Environmental Advisory Council, State of Environment Reporting), National and Provincial Round Table on Environment and Economy, Canadian Council of Ministers of the Environment, Canadian

International Institute for Sustainable Development, Agriculture Canada, OECD, United Nations Development Program's Department for Policy Coordination and Sustainable Development (UNDPCSD), Institute for Perspective Technological Studies (EU), Institute of Arable Crops Research (UK), etc.

There are other techniques to integrate multiple variables. Examples include the input-output analysis developed by Leontif (1970) and environmental impact assessment (EIA), (Glasson *et al.*, 1994). Each of these has its advantages and shortcomings. A brief review of studies using the input-output analysis to evaluate the wider economic effects of a substantial change in agricultrual systems to organic in the UK can be found in Midmore (1994).

While there seem to be an increasing interest in the more comprehensive evaluation of agricultural systems, the difficulties facing scientists in integrating the various components, have probably caused the avoidance of techniques that attempt to quantify impacts, either physically or monetarily, including the CBA technique.

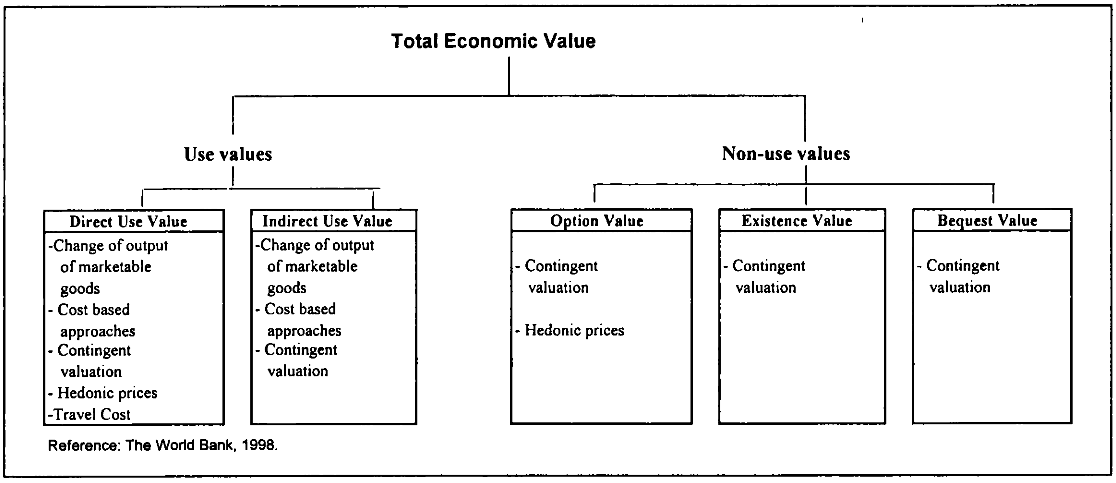
CHAPTER 4

REVIEW OF LITERATURE II:
The Estimation of Impacts

4.1. Physical and Monetary Estimation of Impacts

Of the many significant impacts caused by some conventional agricultural practices shown in Figure 2.1, this study will focus on the direct use values of three categories of impacts: two environmental- soil degradation and water pollution; two social- human health and on-farm employment; in addition to the financial aspects of production. These impacts are listed in more detail in Figure 4.4. A review of the methods (Figure 4.1) most commonly used in the physical and monetary measurement and valuation of the above impacts along with their advantages and relevance to the impacts is presented in the following sections.

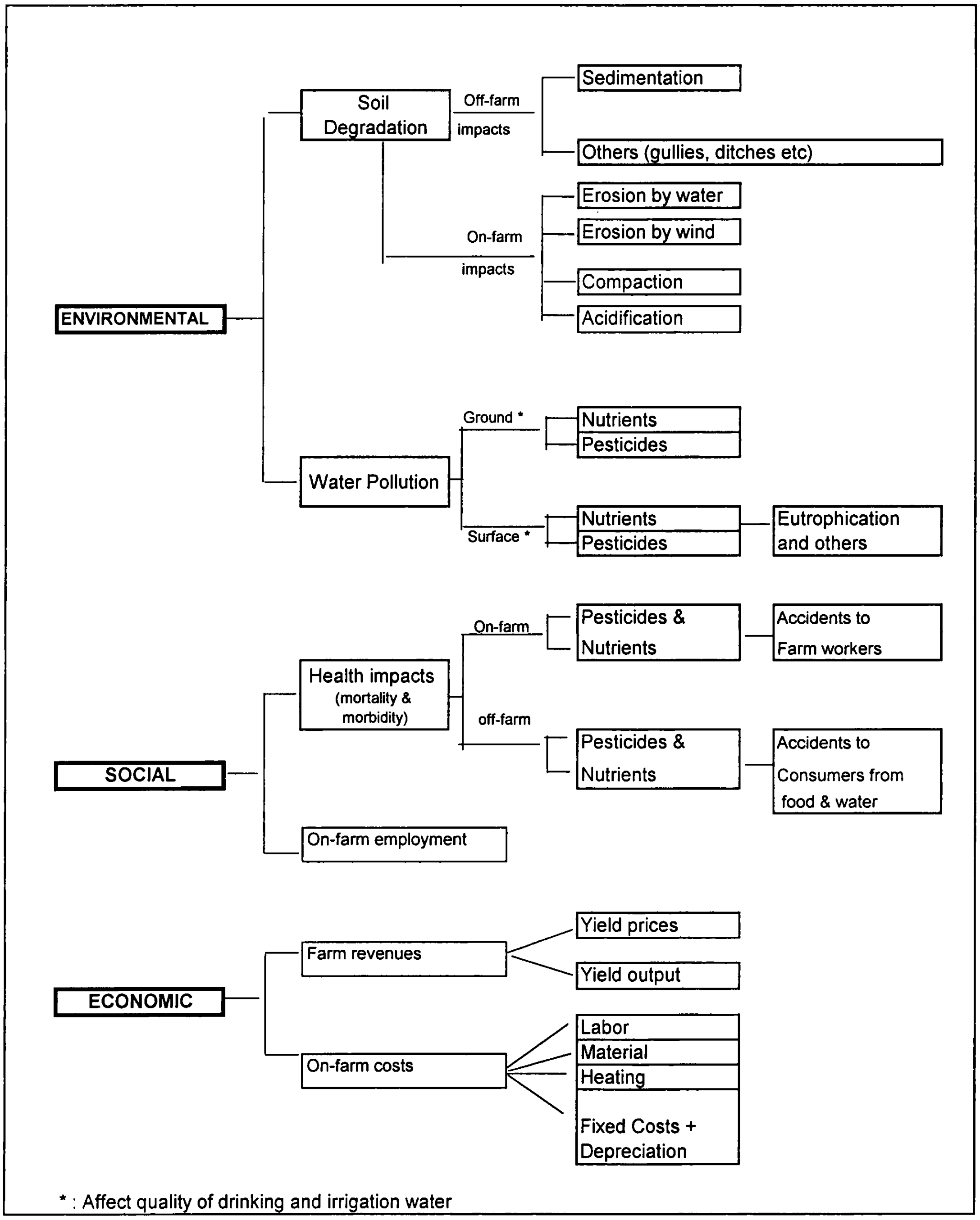
Figure 4.1: Total Economic Value and Selected Valuation Techniques



4.2. Physical Measurement of Impacts of Land Degradation

Four forms of land degradation are discussed in this study. Three of them are on-farm impacts: soil erosion, acidity and compaction (soil salinization is a minor problem in Quebec and will not be discussed any further). The fourth -off-farm effects- mainly involve the impacts of eroded soil on neighbouring fields and water bodies. The impacts of chemicals eroded with soil into water bodies will be included under the water pollution section.

Figure 4.2: The Studied Impacts



4.2.1. Soil Erosion

The most accurate method of determining soil erosion (as well as other land degradation processes) is by frequent field monitoring and measurements over time. This, however, is a costly and a time consuming process, and hence it is impractical. An alternative is the use of modelling techniques.

Of these, the Universal Soil Loss Equation (USLE) has been widely used to estimate soil erosion (Pearce and Warford, 1993). This equation relates soil loss to the product of several parameters, namely climate, soil properties, topography and management variables, according to the following formula:

Soil Loss (A) = R*K*SL*C*P **Equation 4.2**

Where

A= Soil loss (metric tons/hectare)/year
R = Rainfall and run-off erodibility index
K = Soil erodibility factor (Ranges from 0 to 1, with 1 for clayey & 0 for sandy soils respectively
SL= Slope and length of land
C = Crop cover factor
P = Conservation practice factor (=1 if no conservation)

In practice, this equation produced fairly good estimates of soil erosion by water (Trant, 1989). However, the equation may overestimate the net soil loss from a given plot because it does not account for the soil that may have been redeposited on lower parts of the plot or other neighbouring plots (Pagiola, 1994; Lutz *et al.* 1994). In 1997, the equation was re-named the Revised USLE as new data sets were introduced, which affected the evaluation of some of the equation parameters (USDA, 1997). Canadian scientists (Wall *et al.*, 1997) have slightly modified the equation to provide information relevant to Canadian conditions[63].

Other soil scientists (Alt *et al.*, 1989; Faeth *et al.*, 1991; Faeth, 1993; Teague at al., 1995) have used the Erosion Productivity Impact Calculator (EPIC) model. This model was developed by the United States Department of Agriculture (USDA) (Williams *et al.*, 1990)

[63] Their model has been called the RUSLE for Application in Canada (RUSLEFAC).

in the early 1980s to simulate erosion, plant growth, nutrient cycling, pesticide movement and other related physical processes that would occur under different agronomic practices and cropping systems, and to relate these to crop productivity (Putman and Dyke, 1987) under various weather and management practices.. Therefore, the model could be used to analyze alternative cropping systems and help decision makers predict the environmental impacts and economic performance (Jones at al., 1991). The EPIC model relies on the USLE and GLEAMS (a non-point source pollution model, discussed in the next section) models. The model stores an extensive database of soil physical characteristics and weather data for various regions in the U.S., in addition to the results of yield productivity changes from various studies and field experiments. It should be noted that the estimates produced by both models depend on the accuracy of input data for the location being studied (some of which data are not widely available for Quebec).

Wind erosion can be estimated using the Wind Erosion Equation (WEE) (Fox and Coote, 1986; Woodruff and Siddoway, 1965) that was developed by the USDA. This equation relates the extent of erosion damage by wind to soil texture, moisture, surface roughness and wind speed. Mathematically, the WEE can be stated as:

$$C = 386 * \frac{U_z^3}{\left(\sum_{i=1}^{n} 10 * (P-E)_i\right)^2}$$

Equation 4.3

Where

C = Climate factor, that combines soil moisture and wind speed
Uz = Average annual wind speed (m/s) at 9.1 m above ground level
i = months
(P-E) = Monthly Thornthwaite precipitation-evaporation index which is equal to

$$(P-E) = 11.5 * \left[\frac{(P/2.54)}{(1.8T+22)}\right]^{(10/9)}$$

Equation 4.4

Where

P= Monthly precipitation (cm)
T= Mean monthly temperature (Celsius)

This equation has been widely used and has shown good results (Woodruff and Siddoway, 1965).

4.2.2. Soil Acidity

Since (secondary) acidity is mainly caused by the application of nitrogen and elementary sulphur fertilizers, acidity levels can be directly related to the application rates of these fertilizers since the chemical reactions causing increased acidity are well understood[64]. However, acidity levels also depend on the form of fertilizers applied, soil texture and crops produced[65].

Soil acidity can be easily measured with laboratory techniques (soil analysis). It is usually reported in terms of the amount of calcium carbonate (lime) required to neutralise the effects caused by added fertilizers. Researchers consider this an easy measure to use, especially across a variety of land physical properties and production practices (Mehuys, 1984).

When working on a large area, it is only feasible to determine qualitative estimates or ranges of estimates based on available databases. In this case, the requested information should include soil characteristics, fertilizer sales, crops cultivated, amount of nitrogen fertilizers applied and acid rain depositions. The data can be overlaid on maps using Geographic Information Systems (GIS) techniques.

4.2.3. Soil Compaction

Compaction can be estimated by measuring the change in soil physical properties (primarily bulk density) due to the production practices followed on the studied sites. Compaction is a function of machinery traffic (frequency and load), soil water content, soil

[64] Nitrification of ammonia nitrogen and leaching of nitrate nitrogen.
[65] This affects plant uptake rate while soil characteristics affect the amount of nitrates leached from the soil.

physical properties (texture and depth) and organic carbon content. It is also a function of the cropping system, i.e. rotations etc.).

The severity of compaction under various loads and water contents, and the resulting effect on yield are well documented (Amir *et al.*, 1976; Raghavan *et al.*, 1978; Mehuys, 1984). These estimates rely on a combination of mathematical modelling, experimental observations and field measurements of bulk density under different soil and production conditions.

Unfortunately, results obtained from a field experiment can not be always fully transferred to other fields unless the same soil conditions and cultural practices prevail. This can be seen, for example, in the results obtained by Raghavan *et al.* (1978) and Gameda *et al.* (1983) who performed field experiments on corn on different fields in Quebec. Some adjustments and assumptions may be needed to transfer results. Yield change depends on many factors, and can be best estimated with modelling or field experimentation on the same plot. When working on large regions, land can be divided into polygons with various potential impact levels, based on the above mentioned factors. Findings can then be overlaid on maps using GIS techniques (Fox and Coote, 1986).

4.2.4. Off-Farm Impacts

Negative off-farm[66] impacts from eroding soils can occur in various forms. Some of these include damage to: neighbouring farms (gullies, stones etc.), freshwater and marine recreation, navigation, water storage, roadside and irrigation ditches, commercial fishing, municipal and industrial water use, water treatment plants and increased flooding. There is no unique way of measuring these damages. Assessment usually depends on the nature and location of the damage.

[66] Off-farm impacts are by location.

4.3. Monetary Evaluation Methods for Land Degradation

Monetary estimation of land degradation impacts has mostly been calculated based on two methods: 1) The "Dose-Response" method, which considers the value of lost yield productivity[67] due to a qualitative change in an environmental parameter; and 2) "Repair Costs" that includes the cost of added inputs and field operations needed to offset the damage. Additionally, there are other techniques such as Preventive Expenditures and Benefits Transfer. These are also discussed in this section.

The "Dose-Response" method has been suggested and used by several economists (Lutz, 1993; Munasinghe, 1993 and others). In general, the method consists of developing a production function relating yield and soil conservation/erosion levels. This can sometimes be difficult as the change in yield productivity depends on many variables including soil characteristics, weather, crops grown, production practices and the extent of cumulative soil degradation. The method can usually produce good results, but, there are two drawbacks associated with its use: 1) since productivity is changed (affected) only after soil damage (e.g. erosion) has exceeded the soil's tolerance level[68] (T-value), the method does not place an equivalent value for the initial amount of affected soil; and 2) difficulties in the accurate estimation of the relationship, the variables and form of the production function between cumulative erosion and yield. This is a complex issue and is a function of several variables with various interdependent uncertainties and interactions. These include weather, technology and inputs used, method of production, biophysical characteristics of the land, among other factors. Van Vuuren and Fox (1989) also believed that sometimes the loss of productivity might be partially offset by technological improvements implemented on the farm. Despite these difficulties, econometricians can use appropriate modelling approaches

---

[67] The equivalent value of a reduction in yield productivity can be calculated using the following formula:
Costs ($) = Total area impacted (ha)* weighted yield loss (tons/ha) * crop value ($/ton).

[68] The soil tolerance level (T-value) is defined as the maximum rate of soil erosion under which a high level of crop production can be maintained indefinitely (Alt *et al.*, 1989). It is believed that productivity starts to decrease when the rate of soil erosion exceeds 5-10 tonnes/hectare (Agriculture Canada, 1985). This, however, depends on the initial field and soil conditions (depth, organic matter contents, richness with nutrients ..etc.) and nutrient requirements of crops produced.

such as various types of regression analysis[69] to determine such functions between yield and cumulative soil degradation, but only if detailed qualitative and quantitative time series data is available (Pagiola, 1994; Lutz *et al.*, 1994)[70]. When such models are used for certain areas, they are usually checked for consistency with known information[71]. The per hectare loss attributed to erosion is usually measured as the difference between current yield and the yield that would have been achieved if no soil loss had occurred. Economic production data can easily be derived from production budgets, and prices in different markets and geographical locations as well as quantities of demand and supply are widely known.. It should be noted that the government does not offer any subsidies to vegetable production, therefore the market prices for the output are, to a large extent, the result of efficient market mechanisms (i.e. regular forces of supply and demand).

The second method was suggested by Munasinghe (1993), Hanley and Spash (1993) and Repetto and Cruz (1991). It considers the costs of supplemental chemical fertilizers that are needed to replace lost nutrients (original and from fertilizers) so as to restore lost productivity. In addition, it includes costs of additional cultural operations to repair on and off-farm physical damages (gullies, sedimentation in water, etc.) caused by soil erosion. The use of this method satisfies Pearce *et al.*'s (1990) requirement for a "compensating project" to correct for damage and maintain present conditions for future users. However, rational economists, may justify such repair costs only if they are less than the actual and potential costs of soil degradation damage, at least in the short run.

Another related method for the monetary evaluation of soil degradation is to use Defensive Expenditures, which consider the cost of following improved management and conservation practices to reduce erosion and decrease leaching of Nitrogen and Phosphorus fertilizers. Such practices include conservation tillage, vegetative filter strips, contouring, terracing, and appropriate timing, altering rate, timing and method of fertilizer application.

---

[69] In a regression equation, yield is the dependent variable and is a function of cumulative soil degradation, weather, inputs, production practices, time and other biophysical variables.

[70] Such models assume that technology and input use are held constant.

In general, the first method is considered to be more practical to use since values of yield change are easier to collect and use than the costs of repair. As for the second method, since costs of repair are site-specific, i.e. depend on soil characteristics and initial conditions of the land, this limits the use of this technique to comparing fields with similar initial conditions, or fields that are in the same location (otherwise costs will not reflect the severity of the problem). In addition, repair costs may not guarantee that the problem has been completely accounted for (except for acidity) since our understanding of the real extent of damage is often limited.

The Repair Costs method is more suitable to use in estimating a monetary value for acidity. As acidity is a well understood and easily measured problem (compared to other degradation forms), farmers do not have to bear the resulting yield loss since the problem can be almost completely corrected for. In practice, farmers widely adopt this technique and try to maintain soil pH at optimum levels (Mehuys, 1984). The Dose-Response method may not be equally appropriate here since it is hard to build a consistent relation between yield loss and acidity levels as this depends on many factors including soil buffering capacities and other soil characteristics. In other words, soils with similar pH changes would produce different effects on yield, depending on soil type and other physical and chemical characteristics.

The Repair Costs method is also more appropriate for off-farm impacts since these impacts are more significant on water bodies and land profiles than on yields[72], and is usually easier to calculate than the former method. Off-farm costs could include repair of structural damage and maintenance costs to channels, ditches and reservoirs. Estimation of the off-farm impacts caused by eroded chemicals on water bodies is discussed under the water subsection.

---

[71] In some cases, the relation can be estimated from experimentation in labs and controlled environments, but it is usually difficult to completely simulate field conditions.

[72] The Dose Response method can be quite useful if a relation can be established between off-farm impacts like sedimentation or nitrification and fish loss or reductions in recreational activities. However, this is often a difficult issue due to the many variables involved.

The use of the Defensive Expenditures method may prove to be inappropriate in some areas, as certain conservation techniques may prove to be too expensive to adopt either directly in investment requirements (to build terraces, hedges or ditches, for example) or indirectly in forgone production (the value of lost yield in present values) due to the loss of productive land (Baffoe *et al.*, 1986; Stonehouse *et al.*, 1987). Many farmers may also opt to avoid countervailing actions (and hence defensive costs) since the effect on their farms is minimal, even though the off-farm benefits were often greater than additional on-farm costs of soil conservation practices (Fox and Dickson, 1989). It should also be noted that in the above discussion, the prices of inputs or material used in the Repair Costs and Defensive Expenditures methods were considered not to be subject to any governmental subsidy programs. The advantages and disadvantages of various valuation techniques for land degradation are summarised in Table 4.1.

In some cases, the complexity of impacts and limitations of time and money may prevent the estimation of impacts for the site under study. In such cases, the "Benefit Transfer" methodology can be used. Benefit Transfer is "an application of monetary values from a particular valuation study to an alternative or secondary policy decision setting, often in another geographic area than the one where the original study was performed" (Navrud, 1994). This method can be of particular importance in estimating off-farm impacts since these are rather complicated and time consuming to measure. However, the main issues here are the degree to which damage estimate is transferable and what modifications, if any, need to be made to suit the new situation.

The application of benefit transfer can be based on expert opinion or meta-analysis. In the former, experts decide on modifications needed for the results to make the transfer more accurate. To do this, they may consider a variety of factors such as differences in income, number of population, areas under study, extent/size of the polluting activity etc. between the original study and the current one. In meta-analysis, estimates of environmental damage from several studies with different values of variables are analysed using econometric techniques to estimate the responsiveness of damages to various factors, which, may allow a more accurate transfer of results across to other situations. Meta-analysis has been successfully used in environmental studies. Smith and Kaoru (1990) used it for recreation demand and for air pollution in the U.S.

Despite some biases inherent in the transfer of benefits across studies, the Benefit Transfer method can produce good results. The closer the transferred data is to the basic physical phenomena, and the greater the adjustments made for the factors that vary between locations, the more accurate the results (Markandya, 1998).

There are additional techniques that can be used to estimate the monetary values for some components of off-farm impacts such as loss of fishing, landscape values etc. Some of these methods, including the Contingent Valuation, Travel Cost and Hedonic Price methods, are discussed under the water pollution section.

As a final comment, it should be noted that it is obvious that if markets were working efficiently, then the price of a degraded land should be reflected in its market price, whereby it should be worth less than land with similar (natural) characteristics but which has better soil qualities.

Table 4.1: Summary of Monetary Valuation Techniques for Soil Degradation

Valuation Technique	Definition / Represents	Advantages	Disadvantages
1-Erosion by water & wind			
A- Dose-Response method	-Values of lost yield productivity	-Data on yield change is easy to measure	- No value on soil below T-level (productivity unchanged) - Needs good estimation of relationship between erosion and productivity
B- Repair costs	- Costs of additional inputs and field operations to restore previous conditions.	-Used by farmers once they have to repair their fields	- Values are meaningful when comparing similar fields or in same location - Site specific - depends on initial field conditions - May be difficult to completely estimate/ correct for the problem - There may be no need to replace all the lost nutrients since some may have been present in excess
C- Defensive expenditures	- Costs of conservation practices (terracing, wind breaks ..etc)		- Farmers prefer a post-effect action to see if damage costs outweigh conservation costs.
2- Compaction			
A- Dose-Response method	- Values of lost yield productivity	-Data on yield change is easy to measure	- Same as above
B- Repair costs	- Costs of soil amendment operations (subsoiling, installation of drains ..etc)		- Site specific (it depends on soil characteristics & initial conditions - Repair may be damaging (subsoiling) or more costly (drainage) than damage.
4-Acidification			
A- Dose-response method	- Values of lost yield productivity	-Data on yield change is easy to measure	- Not often used since acidity is easily fixed and farmers do not have to bear yield loss. - Difficult to build a unique relation that works on different fields.
B- Repair costs	-Costs of soil amendment that is equal to the costs of lime equivalent to correct pH change	- Correction of pH is an easy process and is widely practiced in Quebec	- Site specific. Depends on soil characteristics. Part of acidity may be caused by non- agricultural operations (acid rain, nature of bed rock..)

Table 4.1- Continued

Valuation Technique	Definition / Represents	Advantages	Disadvantages
5- Off-farm impacts A- Dose-response method	- Value of lost fish catch & reduction in recreational activities etc.		- Difficult to determine an accurate relationship between cause & effect as many factors are involved. - Does not account for non-use values - Some impacts may only show in the long run
B- Repair & maintenance costs	- Costs to repair physical damage (gullies, ditches sedimentation) and prevent further damage	- Many of these costs are paid for in reality.	- Some impacts may be very costly to repair and undergo incomplete repair. - Some impacts can not be completely accounted for.
C- Defensive expenditures	- Costs of conservation practices		- Since many conservation practices may be too costly, it may not be done, if potential damage does not outweigh conservation costs. - Many farmers avoid it since costs fall on the society not the farm.
D- Benefit-transfer	- Considers results of studies in similar areas with some adjustments.	-Overcomes limitations of money and time	- Requires fulfillment of suitable assumptions and adjustments to transfer results.

4.4. Physical Measurement of Impacts of Water Pollution

Estimates of surface water contamination can be measured by chemical analysis of water samples from various water bodies over a period of time. Alternatively, there are several mathematical models that can be used to predict or simulate the amount of chemicals leached into surface and ground water. These include models such as CREAMS, GLEAMS, PRZM, VULPEST and LEACHMN to name a few[73]. These models were developed by scientists using various modelling techniques based on extensive sets of

[73] These abbreviations stand for: CREAMS (Chemicals, Runoff and Erosion from Agricultural Management Systems), GLEAMS (Ground Water Loading Effects of Agricultural Management Systems), PRZM

historical data collected across various locations. These models are faster to implement and cheaper to use than field studies[74]. However, these models require a large amount of input data, which may not always be available, so the operator has to approximate values of the required variables. Furthermore, the models are not user friendly and require technical training for data input and output interpretations. In general, the accuracy of these models varies according to its complexity and the accuracy of its parameter values.

CREAMS and GLEAMS were developed by the USDA's Agricultural Research Service (Knisel, 1980; Leonard *et al.*, 1987) while PRZM was developed at the Environmental Protection Agency (EPA) Environmental Research Laboratory in Georgia (Carsel *et al.*, 1985). LEACHMN was developed at Cornell University (Hutson and Wagenet, 1989). VULPEST is a Canadian model developed by Environment Canada in Quebec (Villeneuve *et al.*, 1987). The first three models have been extensively tested in the U.S. with reasonably good results (Nicks *et al.*, 1984).

The choice of a model depends on the required information, data availability and levels of accuracy needed. It should be noted, however, that the use of these models is limited to small areas (fields[75] or watersheds) because the model parameters account for uniform conditions, which are unlikely to be found for large areas.

4.5. Methods for Evaluating the Costs of Water Pollution

There are several methods that can be used to estimate the (monetary) value of a change in water quality. This depends, to a great extent, on the final use of the water. Of these, three methods have been widely used. 1) The "Defensive (Preventive/Averting) Expenditures" method that considers expenditures made to avoid or reduce incidence of a lower quality change and its potential impacts on health and property. This also includes

(Pesticide Root Zone Model), VULPEST (groundwater vulnerability to contamination by pesticides, from French) and LEACHMN (Leaching Estimation and Chemistry Model-Nitrogen).

[74] While field measurements are costly and time consuming (because they involve an ongoing monitoring process), they produce more accurate information.

[75] A field is defined as a land area having homogeneous soil, spatially uniform precipitation, a single land use and a single management practice system (Knisel, 1980).

the costs of supplying alternative sources of uncontaminated water. 2) The "Damages Avoided" approach which looks at costs of damages avoided due to a conservation or protective procedure. 3) The "Corrective Expenditures" method consisting of costs that are made to restore previous or acceptable conditions. These methods are discussed in the next paragraphs within the context of their applications. Other less common methods, such as the Contingent Valuation, Travel Costs and Hedonic Prices, will also be discussed.

The "Defensive Expenditures" approach reflects Willingness to Pay (WTP) to prevent a change in level of pollution or a certain damage. This WTP is an approximate measure of the estimate of expected/potential damage or benefits to an individual. This method was used by Nielsen and Lee (1987) to evaluate costs of ground water pollution in several areas of potential pesticide and nitrate contamination in the U.S. The authors examined expenses incurred by households to reduce or avoid risks of exposure in both private wells and public water systems. These costs included monitoring of drinking water wells and provisions of alternative supplies of clean water. The authors believed that monitoring was "a first informational step in avoidance strategy decision."

Monitoring costs consisted mainly of testing costs for several pesticides and nitrates[76] in private laboratories. These costs, which also included labour for sample collection and mailing costs, were evaluated at about $173 and $19 per sample for pesticides (average of 4 pesticides) and nitrates, respectively, for a private well. Costs for a public system, that serves a community of 3,300 to 10,000 persons, and extracts water from deeper ground wells, were evaluated at $2560 per year. These costs were multiplied by the number of private wells and community systems to determine overall costs for the potentially contaminated areas.

Nielson and Lee also considered costs of preventive measures for private households, such as the use of filtration units, purchase of bottled water and digging other wells. However, with this technique, it was difficult to estimate an overall national value of such measures since such measures are site specific, and varied according to perception of risk, individuals' attitudes, costs (fixed and variable), effectiveness of options and household preferences.

For community systems, defensive expenditures were calculated as the costs of providing alternative sources of water such as drilling new wells, using surface water and purchasing (volumes of) water from suppliers (Nielson and Lee, 1987). These costs varied significantly according to location and the alternative chosen. Using the same technique, Ribaudo and Hillerstein (1992) considered costs of water softeners and bottled water.

Although this method has the appeal of being relatively easy to calculate, Bartik (1988) has argued that the change in defensive expenditures is a lower bound estimate of benefits from a reduction in pollution since the benefits (of reduced pollution) are valued more than the (preventive) expenditures made. In addition, it is unrealistic to assume that the defensive expenditures will always fully prevent the damage.

Another problem associated with the use of this technique is the fact that defensive or averting expenditures vary according to the individual's perception of risk and personal attitudes (Abdalla *et al.*, 1992). Therefore, the estimates derived from this technique may not capture the complete value of the damage. In addition, there is difficulty in isolating the portion of costs associated with agricultural chemicals since averting expenditures may be made to avoid several pollutants at the same time.[77] However, this is acceptable since corrective measures have to be made even if there was only one contaminant. Estimates of the Corrective Costs method have the same problem.

Another approach, called The "Damage Costs Avoided" was used by Hanley (1990) who assessed the value of a reduction in nitrate levels to the human-safe threshold in drinking water, as the avoided health care expenditures that could have been incurred at high nitrate levels. The problem is using this approach is that it may overestimate the expected damage as potential damage is often not known with certainty.

---

[76] Based on two tests for pesticides at an average cost of $84 per test and $16 for nitrates per test.

[77] Unless agricultural chemicals were the main pollutants.

Crutchfield *et al.* (1993) examined two other methods, a direct and an indirect, to measure the costs of water pollution. The first was the "Corrective Costs" whereby the authors estimated the municipal water treatment costs (i.e. to provide clean and uncontaminated drinking water). This method can also consider costs of reversing the effects of eutrophication or reducing the effects of chemicals in water bodies to permit recreational activities. The second indirect method could be used to determine implicit values for the lost recreational benefits and existence (intrinsic) values of water resources through surveys of individuals.

The latter technique is called the "Contingent Valuation Method (CVM)" whereby, individuals are asked, through questionnaires and interviews, about their WTP[78], a proxy for their personal valuation and a monetary indicator of their preferences and demand level, to have or secure the right to a service, amenity or to prevent a negative environmental quality change (Westman, 1985). In the case of water pollution, individuals are asked about their WTP for general improvements in water quality or to prevent/avoid a decrease in water quality, depending on their current situation. This method aims to reveal values close to those that would be as if a market existed for the good in question.

The accuracy of this model depends on several factors, among which are, the form of the survey (personal interview, telephone call, mail survey, etc), expected paying party for the resulting changes (taxpayers directly or otherwise), means to reach WTP monetary values (open-ended, bidding, payment cards, etc). These issues are discussed in the context of the following paragraphs.

Ribaudo and Hillerstein (1992) believe that this approach is useful in evaluating water quality in a general sense, irrespective of site, and the results can be extended to a general regional population. However, a survey at a national scale would be a costly process. Pearce (1978) noted another disadvantage of this approach: that is the problem of how to convince respondents to reveal their true estimates. Since the questions are hypothetical

[78] Individuals could be asked, instead, about their willingness to accept compensation (WTAC) to tolerate a lower water quality.

(i.e. respondents are not required to pay the price they offer), a difference may exist between the individuals' expressed values and their actual behaviour. This is important as the aim behind determining WTP levels is to find the effective demand, which not only looks at quantity but should also be backed by ability to pay. Respondents may even provide biased answers in order to influence choices about desirable public facilities. This is called strategic bias (Rose, 1990). In addition, since values of WTP are dependent on individuals' income, respondents may not be able to express their true preferences since they are restricted by their ability to pay. In this case, individuals with higher income may express a higher value of WTP than lower income individuals even if both individuals had similar preferences (Bromley, 1985). Another source of bias is that values of WTP depend on the participants' perception of risks involved. It is believed that the effects of changes in environmental quality on the ecosystem, individuals health and welfare differs among individuals, and are often not well known by the general public (Hufschmidt *et al*, 1983) who usually leave such judgements /decisions to governmental agencies (Schulze, 1994).

Boyle and Bishop (1988) have listed additional criticisms of this technique. The format of questions administered affects the expressed WTP values. For example, one CV technique, the Iterative Bidding, checks the respondent's WTP (acceptance to pay) for an initial bid, then the interviewer changes the bid incrementally (higher or lower depending on response to the first bid) until the respondent accepts the new value. This type of bidding is believed to have a starting point bias since the initial bid may influence the respondents' final bids.

In addition, the method of payment proposed in the questionnaire may affect the expressed values. In this case, WTP for a local development is expected to be higher if the project is to be financed with funding from the federal government, for example, instead of increased local taxes (Cummings *et al.*, 1986).

Despite these issues, it is believed that many of the problems encountered in CV could be avoided by proper sampling, design of questionnaires and improved statistical analysis

(Boyle and Bishop, 1988). In such cases, results would usually be broadly consistent[79] with those derived from other valuation methods (Winnett,1998). Additionally, CV could be combined with other techniques to improve conclusions (Brouwer *et al.*, 1999)[80].

Ribaudo and Hillerstein (1992) discussed another method, the "Revealed Preferences Method". This is based on the notion that a change in quality of an environmental parameter, such as water, is reflected in the market for other related goods, such as a change in demand for water-based recreational activities[81]. This can be computed by using either the "Travel Cost Technique" or the "Hedonic Property Analysis"[82]. Both methods are indirect ways to measure the value of an environmental quality change. The former estimates the amount spent (value of time[83] and expenses incurred) by individuals, from different geographical areas, to travel to a recreational site. This will reflect, indirectly, the demand curves and values placed on the quality of environmental amenities present. The latter measures the effect of a change in environmental quality, such as noise or air quality, for example, on property prices. The main advantage of these techniques is that they use market data, which is also based on actual behaviour. One of the disadvantages of the Travel Cost Method lies in it being a data-demanding method, and it is site specific so that results can not be easily extended to other sites. The difficulty in applying the latter method, Hedonic Pricing, stems, in many cases, from lack of data availability.

The shift in demand (curve) for a certain good or its proxy, as a result of a change in quality can be measured by the change in consumer surplus[84]; the area under the demand curve but above the price. This is usually easy to measure if the demand curve was known. The demand curve can usually be found using surveys (i.e. the CV method).

---

[79] Consistency means here that estimates are within plus or minus 100% of each other.

[80] Brouwer at al. (1999) believed that public attitudes and preferences towards the environment could be best elicited when individual WTP based studies (e.g. CV) are combined with a participatory social deliberation approach (focus groups).

[81] A change in water quality will affect demand for water recreation.

[82] Additional information on the Travel Cost Method and Hedonic Property Analysis can be found in Munasinghe (1993), and Dixon and Hufschmidt (1986).

[83] Economists estimate it to range between a quarter and half of the average wage.

Ribaudo and Hellerstein (1992) also suggested the use of the Dose-Response method, which considers lost revenues due to reduced recreational activities and fish catch in affected regions. This method may be useful if a relation can be established between the pollutant and the extent of damage.

While each method has its merits and disadvantages, the choice of an evaluation method depends on data availability, the skill of the researcher and the environmental variable being evaluated. The advantages and disadvantages of these techniques are summarised in Table 4.2.

---

[84] Hanley and Spash (1993) show that change in consumer surplus is a good measure of welfare changes.

Table 4.2: Summary of Monetary Valuation Techniques of Water Pollution by Agricultural Chemicals

Valuation Technique	Definition / Represents	Advantages	Disadvantages
A-Corrective expenditures	- Costs to restore previous or acceptable conditions. For domestic use, these include municipal water treatment costs	- Does not require assumptions on extent of damage or reaction of public	-Works only for areas with treatment plants -Difficult to isolate costs of agricultural chemicals from other pollutants
B-Defensive expenditures	-Expenditures to reduce/avoid the problem. For domestic use, this includes costs of filtration units, costs of providing alternative sources of drinking water (bottled water, digging other wells) and monitoring costs, etc.	-Depends on market prices of relevant goods - Works for areas with no water treatment plants	-Expenditures vary according to people's perception of risk. - Costs are site specific - May overestimate costs if contamination is insignificant (since it varies with season & across regions) - Difficult to isolate costs of agricultural chemicals - May underestimate damage because of imperfect substitutability.
C-Costs of damages avoided	-Represents the avoided expected costs (of potential damage) due to improvement in environmental quality	- Not site specific	- The extent of potential damage on aquatic systems and impacts on health is not known with certainty

D- Contingent valuation	- Based on surveys to reflect implicit values of lost recreational benefits & other existence values.
	- Reflects WTP, a proxy for personal valuation
		- Solution to the absence of relevant markets.
		- Can be used for use & non-use values
			- National scale surveys are expensive
			- Many sources of bias:
			  - Surveyed individuals may not reveal their true values
			  - Values are based on perception of / and importance of problem
			  - Depends on question format, individual's income & paying party
			- Valuation depends on potential behavior

E-Revealed preferences	- Reflects a change in the value of a marketed good due to a change in environmental quality	-Valuation depends on actual behavior and market information - Can be used for use & non-use values	
Travel cost			-Results are site specific
Hedonic prices			-Site specific & depends on availability of extensive data

4.6. Social and Health Issues

The two impacts to be considered in this study are on-farm employment and health impacts.

4.6.1. On-Farm Employment: Quantitative Impacts

In general, on-farm labour requirements vary widely even within the same production system. This depend on types of crops produced, type and size of machinery and equipment available on farm, production methods, soil type and topography and overall labour and management efficiency (USDA, 1980).

Since many operations in organic farming systems are labour intensive, organic farms have higher labour requirements (on per area basis) and consequently higher labour costs than conventional farms (Altieri *et al.*, 1987; Jansen, 2000; Lampkin, 1986; Offermann and Nieberg, 2000). Lampkin believes that this is especially true for vegetables because of greater crop protection and weeding needs. Some vegetable crops do not tolerate any disturbance to their roots or leaves during mechanical weeding, and therefore hand weeding is used (using a hoe, or a hand driven rotary tiller).

In organic production, labour is also extensively used in pest control measures[85], compost preparation, harvesting and other cultural practices such as inter-cropping (McRobie, 1990; Percival, 1984) as well as from other ways of marketing and processing the products (Jansen, 2000). The latter author feels that increased labour on organic farms should be seen as due to an increase in total on-farm tasks rather than more labour hours for specific operations. It is difficult to estimate a fixed figure for additional labour requirements for organic farming as it depends on the crops planted, geophysical conditions, pest infestation levels, available machinery, production methods, etc., but the literature reviewed indicate that it generally does not exceed 50% over the requirements for conventionally-produced vegetables. Additional labour requirements for organic vegetable production can be

[85] The practices involve hand picking or sucking up (using an aspirator) of larger pests.

measured by estimating the number of additional labour hours required to perform production practices per hectare of land.

4.6.2. Human Health Impacts

The impacts on humans are due to either farm accidents (to applicators and farm neighbours in heavily treated agricultural land) or the consumption of food contaminated with chemical residues. The latter is of particular importance in the case of fruits and vegetables since these typically receive the highest dosage of pesticides among the crops.

Valuations of risks associated with an agricultural chemical under the conditions of use is termed risk assessment. Risk assessment is comprised of two components: measurement of chemical toxicity (dose-response) and measurement of the extent and duration of exposure to an individual or a population in a particular situation (Extoxnet, 1993).

To predict potential human toxicity and establish a relationship between a particular chemical (active ingredient) and health (dose-response relationship), two types of studies can be used: 1) investigations of human populations (epidemiological studies); 2) experiments on laboratory animals. It should be noted, however, that toxicity assessment is a complex process and is affected by temperature, light, humidity and animal characteristics (Extoxnet, 1993; Briggs, 1992). Laboratory tests are usually a reliable mean to determine the chemicals' toxic and lethal doses (TD and LD).

The TD50 indicator reflects the dose that will produce signs of toxicity in 50% (averaged out over many tests) of the animals tested. Similarly, LD50 is the lethal dose for 50% of the animals tested. These doses, expressed usually in terms of mg of chemical per kg of body weight, are a function of animal species and route of exposure. The smaller the TD50, the more toxic it is. Both measures are important because a chemical may cause illness at a small exposure level while it may cause lethal results only at high concentrations.

Acute toxicity is easier to assess and understand than chronic impacts (Briggs, 1992). Short-term studies on animals help to determine the associated adverse effects and the doses at which these effects occur. Often, some human experience is available as a result of accidental exposures. Chronic toxicity is assessed using a variety of specific tests for adverse effects such as reproductive damage, behavioural effects, cancer, etc. These depend on both laboratory animal tests and mathematical modelling. Laboratory testing takes a considerable length of time and may extend for a period beyond the animals' lifetimes, as some effects may only show in the next animal generation. Moreover, there is more uncertainty involved with chronic assessment than with acute assessment (Extoxnet, 1993; Briggs, 1992).

Exposure assessment, on the other hand, can be determined from either the analysis of exposure source (drinking water, food), measurement of environment (air, human blood or urine) and laboratory tests. These provide data on present situations and not past exposure levels. Furthermore, the analysis of human body fluids may reveal the existence of exposure but not the duration or source of exposure. Toxicity may appear in different forms, since reactions may differ among various people, and it may be difficult to correctly identify the source of toxicity due to synergistic effects and because non-agricultural compounds might show similar symptoms. This reflects the limited understanding of what happens to persistent chemicals in the body (Extoxnet, 1993).

Although the physical characteristics of most agricultural chemicals and the effects on non-target species are well documented (Briggs, 1992), it is often difficult to precisely correlate the effects on animals to those on humans. However, such studies are useful or at least widely used in setting safe standards for human exposure and residues in environment.

Several organisations such as the United States Environmental Protection Agency (US-EPA), Environment Canada and Environment Quebec have set up safety standards including characteristics and maximum contents of chemicals in water, for water used in drinking, irrigation and for the preservation of aquatic life. These standards often vary between countries, some of which follow stricter norms than others. In addition, such standards are constantly being revised as the state of knowledge increases about the potential impacts of chemicals.

4.7. Monetary Evaluation of Social and Health Issues

4.7.1. On-Farm Employment

Several studies have examined the additional number of jobs created by alternative production methods (e.g. Jansen, 2000; Padel and Zerger, 1994), but none has placed a monetary value on their effect on the economy. Therefore, the monetary estimation of job creation will be evaluated using various macroeconomic tools and by considering the opportunity costs of unemployment to the society. These will be discussed under the relevant section in the Methodology chapter.

4.7.2. Health Impacts

Changes in environmental attributes will lead to changes in the incidence of diseases and consequently, life expectancies. Three categories of costs can be associated with related negative health impacts (i.e. mortality, morbidity or accidents): 1) direct costs that include expenditures made by the patient for diagnosis, treatment and rehabilitation; 2) indirect costs that consist of the value of lost output and earnings due to the cessation or reduction of productivity; and 3) psycho-social costs that result in reductions in the quality of life of the victims, their family members and friends. These latter costs are difficult to assess (Hodgson and Meiners, 1982). Thus, the majority of studies have focused on the direct and indirect costs.

Of the many methods used to place a monetary value on negative health effects, three methods have been widely used: 1) The "Human Capital" approach (HC); 2) the "Contingent Valuation"; and 3) the "Preventive Expenditures" methods.

The first method, which is frequently used by many insurance companies and the court system, equates the value of an individual's (lost) life or days of sickness with the forgone value of his labour (or productivity) due to working time lost because of premature death, injury and sickness (absenteeism)[86]. This value is equal to the discounted projected future

[86] Insurance companies in developed countries commonly use the value of a statistical life (VOSL).

(gross) earnings of the victim[87]. According to Mishan (1972), the value of an individual's labour can be mathematically stated as:

$$L = \sum_{t=T}^{\infty} \frac{Y_t * P_T^t}{(1+r)^{(t-T)}}$$ Equation 4.5

Where

L = value of individual's labour
Yt = individual's expected gross earnings during the t-th year according to age, sex and education.
P^t_T = probability in year T that the individual is alive during the t-th year.
r = discount rate
t, T = time frame (years)

This approach has been criticised by many on ethical grounds since this method substitutes life which is sacred and has an infinite value in monetary terms (Pearce, 1978). However, in practice, society implicitly places value on human life and illness in many policy decisions (Hyman, 1981; Munasinghe and Lutz, 1993). In reality, what is measured here is not the value of life per *se*, but more or less, the value on the saving of a life. Alternatively, the lost value of productivity for a year of life can be estimated from the value of a statistical life (VSL), (Markandya, 1998). (VSL is explained is the next paragraphs).

The HC method has other significant shortcomings. 1) It does not account for the value of emotions, pain and suffering of the individual or his family members due to sickness or death, which could be significant. 2) The method does not place any economic value to non-productive (or non-earning) individuals such as children, volunteer workers, handicapped and retired people, and may undervalue some groups relative to others (e.g. women versus men); 3) It ignores individual preferences for the reduction in risk.

[87] Gross earnings are considered since the analysis is done from a societal perspective. The individual is a member of the society and all of his earnings are eventually returned to the society, albeit in various forms, i.e. savings, consumption etc.

Additionally, a society may consider an individual's worth to be more than merely a productive asset (Hufschmidt *et al.*, 1983), irrespective of sex or age.

It should be noted that the use of this method to place a monetary value on an environmental externality relies on establishing a reasonable relationship between the environmental parameter (i.e. pollution) and its effect on human health. Identifying the cause-effect relationship is often a difficult issue, and this restricts the range of applications. Nevertheless, this approach has been widely used since it is relatively easy to apply, and because it uses market data and prices.

The second approach, the Contingent Valuation (CV), consists of interviews and questionnaires administered to participants, to determine their WTP for improved health conditions and/or reduction in risks of sickness or death. Alternatively, individuals may be asked about their willingness to accept compensation (WTAC) for increased risk[88]. This value is then converted into the value of a statistical life (for the group) by dividing the WTP by the change in risk. Although the CV technique may have some bias (Section 3.6), it is believed that this method is, in general, the more appropriate measure to determine the monetary value of life and impacts on health (Lutz and Munasinghe, 1993; Hufschmidt *et al.*, 1983), since individuals are the best persons to value their own health[89], and therefore, they may be willing to pay several times more than their expected earnings for improvements in life expectation and/or risk reduction. Furthermore, this approach involves a comprehensive consideration of all potential costs of illness or death borne by the individual[90], i.e. direct, indirect and psychosocial (Hodgson and Meiners, 1982).

In buying a life insurance policy, the price paid by an individual reflects the value he/she sets on his/her life, including his/her concern for the family and dependants (Jonsson,

[88] Some researchers believe that salaries or increased compensation received for riskier jobs do reflect the WTAC values, if the individual accepted a riskier profession by choice and not due to lack of other opportunities or immobility across markets.

[89] This idea is in line with the concept of consumer sovereignty which suggests that individuals affected by any project (being considered) are the best judge of its value.

1976). The price also reflects the WTP for one's life given the expected probability of death.

The valuation of WTP was handled using a dynamic approach by Freeman (1993), who considered a time dimension for the analysis. As current actions may influence the probability of negative impacts on health in the future, Freeman has developed a life cycle model of WTP for avoiding risk at the current time for a change in the conditional probability of dying at various ages. The model showed that the longer the latency period, the smaller the WTP.

One of the important biases in using this approach is the fact that WTP values are dependent on income, i.e. on ability to pay. A poor man may thus place a lower value on his life than a rich man, and consequently, such inequalities within a society may result in differing valuations of the environment. However, as such inequalities in income and wealth do exist, such differences in evaluating environment, health and life can be justified (Markandya, 1998).

Nielson and Lee (1987) noted that values of health could also be deduced from preventive/ defensive expenditures, which are increased voluntary expenditures to avoid potential health risks (in general or from certain activities). In the case of polluted water, costs may include the purchase of filtration units and bottled water or even relocation in certain extreme cases. Other general examples within the same context include costs of seat belts, smoke detectors and air bags (Hodgson and Meiners, 1982, Markandya, 1998). However, preventive costs may vary significantly since the perception of potential risk within a community is not invariable. Furthermore, there may be a difficulty in accurately determining the function between inputs used by the individual and different health states, as many inputs may provide for more than one service, and as changes in consumption patterns due to various illness states are difficult to estimate (Markandya, 1998). Additionally, this method makes an unreasonable assumption as it presupposes a linear

[90] CVM may not include altruistic costs, i.e. those borne by relatives to the sick person including pain and suffering.

relation between the reduction on the probability of morbidity and the costs assumed by an individual in order to reduce this probability.

Another approach is accounting for the avoided health care expenditures that would have been incurred if sickness occur. This would also give an idea of the direct human health costs involved (Hanley, 1990).

In reviewing several European and North American studies done from the early 1970s to the late 1980s, Markandya (1998) noted that on average, the highest values of a statistical life came from CV studies. This may be justified as CV studies encompass most of the costs involved.

Each of the methods discussed above has its shortcomings. The first was proclaimed incomplete, the second was based on a hypothetical situation and had bias, and the values of the third were considered incomplete. While the CV method may theoretically be considered as the more appropriate technique, the relative simplicity of the HC and its reliance on market data and prices (instead of the hypothetical values of CV), make it a more favourable option. Hence, the Human Capital method can be considered as a second best option as long as the analyst regards the results as minimum estimates of the values placed on human life. Alternatively, a combination of methods can be used, such as the sum of lost earnings plus treatment expenditures in addition to the opportunity costs of leisure[91]. These combined, make up the total cost of illness[92]. In the case where a worker returns to work but his productivity is decreased, an estimate of productivity loss has to be included (Markandya, 1998).

The appropriate method to use depends on the situation under study, data availability, skills of the analyst and moral and ethical values present in the society. The advantages and disadvantages of each method are listed in Table 4.3.

[91] Opportunity cost of leisure is typically valued between one half and one third of the post-tax wage (Markandya, 1998).

[92] The cost of illness approach does not include avertive or preventive expenditures.

Table 4.3: Summary of Monetary Valuation Techniques of Health Impacts

Valuation Technique	Definition / Represents	Advantages	Disadvantages
A- Human Capital Approach	Value of lost wages or lost (life) productivity	- Depends on market data - Easy to use - It is currently widely used	- does not account for psychological costs - Dos not place a value on non-productive people - Sometimes rejected since health and life should not be valued monetarily
B- Contingent Valuation	- Surveys to find willingness to pay (WTP) for improved health conditions/ reductions in risk OR willingness to accept (WTA) for the opposite.	- Reflects WTP, a proxy for personal valuation - Accounts for all costs (direct, indirect and psychological) - Individuals can best estimate the value of the their own health	- Technique has bias - Valuation depends on income - Valuation depends on potential / hypothetical behaviors - Valuation depends on perception of risk
C-Preventive Expenditures	- Expenditures to avoid the problem & reduce risk	- Depends on market prices	- Costs vary according to perception of risk
D- Avoided Expenditures (on health care)	- avoided expected costs of medication and hospitalization	- Uses market values	- Reflects only direct costs

4.8. The Economics[93] of Organic Vegetable Production

There have been many studies that attempt to evaluate the economics of sustainable agriculture, and organic vegetable production in particular (e.g. Sellen *et al.*, 1993; Lampkin, 1994; Offermann and Nieberg, 2000 etc). Most have been done on the farm level.

Production costs depend to a large extent on the production methods followed. These vary depending on factors such as farmers' experience or management skills, soil characteristics, available machinery, farm location, climate etc.

Lampkin (1994), Offermann and Nieberg (2000) report that operating costs in organic systems are quite variable but tend to be slightly lower than comparable conventional systems. The decrease ranges between 50-60% for grains and between 10-20% for potatoes and horticultural crops. A survey of a sample of Canadian organic farmers estimated cost

[93] The term economic here is used narrowly to refer to financial aspects.

savings to be about 18% (Weymes, 1990). In general, organic vegetable production requires lower amounts of inputs than conventional production: Synthetic chemical compounds are replaced by natural products and cultivation practices (to replace nutrients and control pests) (Mckinney, 1987). However, there have been cases where input costs were higher due to the purchase of compost and organic fertilizers (Sellen *et al.*, 1993). Labour costs are the main expense and tend to be higher in organic production (including family labour) because many operations are more labour intensive[94] (Knoblauch, 1990; Jansen, 2000; Offermann and Nieberg, 2000; Padel and Zerger, 1994; Stonehouse *et al.*, 1993 and). Some estimate it to be between 20 to 100% higher depending on crops, production methods, etc (Lampkin, 1994). Organic farming systems tend to be less energy intensive in producing most crops than conventional farms (USDA, 1980; Oelhaf, 1978; Mckinney, 1987). This is mainly attributed to the lesser reliance on mechanisation and synthetic chemicals (and thus fossil fuel).

Studies have reported different variations in vegetable yields (quantity and quality according to marketing standards) on a per hectare basis, between organic and conventional production systems. (Oelhaf, 1978; Lockeretz *et al.*, 1989; Henning, 1994; Sellen *et al.*, 1995). The difference in yield varied considerably based on crop, weather, soil conditions, cultivars used, position in the rotation, production method, experience of farmers, etc. (Lampkin, 1993). Therefore, it is difficult to determine a reliable constant figure. Yields under organic production could be anywhere between 55% to 100% of the conventional yield in the same region once rotation systems become established. Offermann and Nieberg (2000) reported that organic vegetable yield is often equivalent to that under conventional production. Some scientists believe that the yield gap is expected to diminish in the future with more developments in organic research, technological developments and improved management abilities (Lampkin, 1994).

As for prices, organic produce had an additional premium (both at the farm and retail market levels) due to the high demand for the produce (Lampkin, 1993) and increased

[94] Labour is used in hand weeding, some pest control measures, compost preparation, harvesting and a higher level on-farm packaging and processing activities.

consumer preferences (Henning *et al.*, 1994). The premium was quite unstable and varied according to season and crop ranging from 20 to 200% (in exceptional situations) with an average of about 30% (Henning *et al.*, 1990; Henning, 1994). At the retail level, it is believed that consumers were resistant to premiums exceeding 30% (COG, 1990).

In general, studies have generally found that the net margins (on area basis) for organic crops tend to be similar or higher than conventional crops, with some variations, if price premiums were obtained, but gross margins were lower otherwise. In general, higher prices and lower input costs were often able to offset lower yields (Steinman, 1983; Wagstaff, 1987; MacRae, 1988 Lockeretz *et al.*, 1989, Stanhill, 1990; Patriquin *et al.*, 1991; Burgoyne, 1992 and Offermann and Nieberg, 2000). This depends on many factors including intensity of cultivation, diversity of the organic system, degree of reliance on external input, in addition to the typical factors such as experience, soil, rotation plan, marketing venue, markets, location/region, etc. Additionally, the economic performance was affected by the governmental support payments in many European countries (Offerman and Nieberg, 2000). Fixed operating costs (repairs, depreciation, property charges etc.) tend to be similar for the two farming systems but initial investment in machinery (for organic) tends to be lower.

It can thus be concluded that organic farming systems can be as economically viable as conventional systems with proper management skills.

In Quebec, since 1990, the CREAQ research department at the Ministry of Agriculture has published production budgets for only two organically grown crops: cabbage and carrots. The yield of cabbage was similar to conventional produce (because the same number of heads/hectare were planted) but the yield for organic carrots was 15% lower. The selling prices were two and six times higher than conventional prices for cabbage and carrots, respectively. Gross margins/hectare (excluding fixed costs) for organic cabbage and carrots were three and five times higher than for the conventional product.

There are few other Canadian studies on the economics of organic vegetables[95]. Sellen *et al.* (1995) concluded, in a study comparing the economics of production for five vegetables (sweet corn, green beans, cabbage, tomatoes and Spanish onions) that average organic yields were lower than the conventional yield with reductions ranging from 8% for green beans to 45% for tomatoes. Input costs were higher for organic crops (17-35%) except for tomatoes which was 19% lower. To have comparable net revenues, organic vegetables required a price premium, which ranged from 13% for cabbage to 57% for sweet corn. Surveys of organic farmers made by Weymes (1990) and Van Bers (1990) showed that the yield differential was quite variable, exceeding the conventional in certain cases, but was slightly lower on average (6%). Another survey made by COG (1990) noted that production costs for vegetables were 5% lower than the conventional and the price premium was about 71% on average.

In general, results seem to be quite variable given the many variables involved, of which management, labour and inputs seemed to play an important role. However, there seems to be a need for more extensive studies on the economics of organic vegetable production in Canada, in general, and Quebec in particular, before conclusive opinions or generalizations can be made.

[95] There are several studies on the economics of other organic crops, especially grains and oil seeds (e.g. Schoney and Culver, 1991; Rutherford *et al.*, 1992; Stonehouse, 1996 etc.), which are the major organic crops produced in Canada. It is believed that Canada is among the top five world producers of these organic products, with an estimated retail value of C$1 billion. (Agriculture and Agri-food Canada, 2001).

CHAPTER 5

EXISTING EMPIRICAL STUDIES OF QUEBEC AGRICULTURE

5.1. The Situation in Quebec

The province of Quebec is the second largest province in Canada after Ontario. It occupies an area of 1,542,056 square kilometres or about 15.45% of the total area of Canada (Canada's area is 9,976,140 square km). The total population is 7.35 million, which constitutes 24.3% of the total Canadian population (30.25 million) (Statistics Canada WebPages, 2000).

The Quebec economy is diversified. It depends on industry, services, agriculture and tourism. The total GDP was estimated at 147.4 billion Canadian dollars (C$) in 1997, of which the agri-food sector contributed approximately 12 billion C$ or almost 9% of Quebec GDP in 1997. The sector employed 389,100 people in 1997 or about 11.9% of the provincial workforce; i.e. one job in nine was generated by this sector. Of these, some 75,000 were on-farm jobs (124,000 including seasonal). Family labour accounted for 68,000 jobs, while 87% of hired labour was seasonal (Quebec Ministry of Agriculture, 1998).

In 1999, there were about 31,600 farms in Quebec, occupying an area of 3,186,556.2 hectares. Of this area, crop production covered 2,329,372.6 hectares. The largest area was planted with forage crops (39.85%) followed by grains and high-protein oilseeds (32.1%), pastureland (16.48%), potatoes and other vegetables (2.54%) and fruits (1.23%) (Quebec Ministry of Agriculture WebPages, 2000). The highest crop earnings in 1997 were generated by fruit and vegetables (36.4% of all crop sales) followed by grains and oilseeds (33.2% of all crop sales), and ornamental horticulture (12.5%) (Quebec Ministry of Agriculture, 1998).

The province has been divided into 17 agricultural regions for administrative purposes. These are shown in the map below.

Most of the agricultural activity in the province takes place in the Monteregie region (region No. 16). The area of the region is 11,059 sq. kilometres, and is home for about 1.32 million inhabitants (17.8% of the province's population). It has about 7500 crop producing farms occupying a total area of 647,000 hectares and employing 19,400 full time agricultural employees or 18% of the total provincial agri-food labour force (Quebec Ministry of Agriculture, 1999).

Figure 5.1: The Administrative Regions in the Province of Quebec

Reference: Quebec Ministry of Agriculture WebPages, 2000.

5.1.1. <u>Overview of the Organic Vegetables Industry in Quebec</u>

It is estimated that there existed 501 certified organic enterprises in Quebec cultivating an area greater than 13,000 hectares in 1996. About 95 enterprises or 19% of these enterprises produced vegetables (Canadian Organic Growers Association (COG), 1997). The Quebec Ministry of Agriculture (1999) reported that about 2000 farmers produced some organic crops, of which 1000 farmers were in the transition process (from conventional to organic production methods). The number is relatively significant as it involves about 8% of farming enterprises in Quebec (COG, 1997). The total farm area planted by organic vegetables is estimated at about 600 hectares.

The Canadian Organic Growers Association (1990) noted that the local demand for organic food of all types exceeds domestic production in the Canadian markets. This shortage in domestic supply is being alleviated by imports, primarily of fresh fruits and vegetables.

The value of (retail) sale of organic produce in Quebec was estimated at $35 million in 1994[96] (Radius, 1994). No recent figures exist for the sales of organic fruits and vegetables beyond the 1988-89 season, that was estimated at $1.85 million by the Féderation d'Agriculture Biologique (Hébert, 1989). However, a 1994 personal communication with some distributors[97] of organic vegetables in the Montreal area, suggested that the current figure was much larger, since the demand for fresh vegetables has been steadily increasing at a rate of 15-20% per year since 1989. These findings reflect the increasing economic importance of this industry in Quebec.

The organic movement has been supported in this province since the 1970's by government policies that promoted the development of organic production. In 1989, the Quebec Ministry of Agriculture (MAPAQ) proposed an "integrated plan of intervention" in which three million dollars were contributed to support the development of the organic movement over the following three years. This money was provided to help restructure the province's industry and to supply technical assistance to both existing organic farmers and those making the transition to organic methods. Currently, MAPAQ maintains its support through (partially) financing the extension sector to enhance training and distribution of information through organizations such as Le Centre de developpement d'agrobiologie de Warwick, Le service d'information AGRO-BIO, and Le Centre de d'agriculture biologique de La Pacatiere.

In response to continuous governmental support and advice, Quebec's agricultural sector started to adopt a phyto-sanitary strategy in 1992 aimed at reducing pesticide use and promoting pest management. Accordingly, pesticide sales in 1996, measured by kg of active ingredients, showed a 7.5% decrease over 1992 figures. Most significant, were the

---

[96] Of which 84% of the sales were attributed to imported produce (Radius, 1994).

[97] Including Distribu-vie and Terre a Terre.

reduction in fungicides and insecticides usage by 35% and 48%, respectively (Quebec Ministry of Agriculture, 1998).

The number of agro-environmental advisory clubs and technical support organisations is increasing in the province. In 1999, the number exceeded 60 organisations with a membership of more than 3,000 persons. These clubs play a proactive role in raising awareness of environmental concerns and help to promote sustainable farm practices. One of the prominent organisations is Quebec's Plant Health Warning Network (PHWN) with a membership of about 3,521 members. The PHWN helps farmers implement new pest control techniques and offers advice on proper pesticide use. As a result, farmers have shown growing interest in practices that favour water and soil conservation. In 1996, about 10% of farms used a cropping system that involved zero tillage. Other practices involve improved manure management, direct seeding and less intensive use of pesticides.

The provinces of Quebec and British Columbia were the only Canadian provinces to enact laws governing organic standards, which has given a strong credibility to the organic movement. The standards outline production, processing and labelling requirements for organic products. The accreditation system in Quebec meets the International Organization for Standards (ISO).

These findings reflect the growing interest in sustainable development through conservation practices and increased awareness by government, farmers and consumers.

5.1.2. Land Degradation in Quebec: Physical Estimates

Before 1985, there were few studies that examined the extent, rate of increase, and economic impacts of land degradation in Quebec and the rest of Canada (Coote, 1983; Bentley, 1981; Anderson and Knapik, 1984). Much of this was attributed to the lack of adequate regional inventory data and insufficient information on the amount of degradation and its effect on yield. Anderson and Knapik (1984) noted that, until 1984, such regional studies were not available except for few plot level experiments. Since then, efforts by the Ministries of Agriculture and Environment of Canada and Quebec have increased the amount of available information on land degradation. The Senate Task Force report, "Soil at Risk", released in 1985, was a descriptive review on the extent and location of land degradation, but it did not provide any economic analysis.

It is believed that the first real estimates of the extent and costs of agricultural land degradation in Canada were the result of a joint venture by Statistics Canada and Agriculture Canada in 1985/86 (Trant, 1989). The two organisations cooperated in the Land Degradation Task Force, to assess the extent, impacts and costs of agricultural land degradation in Atlantic and Central Canada and Southern British Columbia (Fox and Coote, 1986). Using a large data base on physical soil characteristics, Fox and Coote were able to determine the extent of land degradation in its various forms, based on modelling techniques[98], subjective estimates, questionnaire sets and meetings with selected groups of experts. It is believed that this study is the most comprehensive work that has been done so far, for these regions. Other major works include those of Trant (1989), Fox and Coote (1986) and Tabi *et al.* (1990). The latter study is believed to be the last major study on land degradation in the province (personal communication with G. Mehuys, 2001)[99].

Most erosion studies have used the Universal Soil Loss Equation (USLE) whose parameters were determined for the various regions of Canada by collaborative work between Statistics Canada and Agriculture Canada (1986). Trant (1989) used these findings, to get national erosion estimates on a regional basis. Using another technique, Trant (1989) applied the Geographic Information System (GIS) technology to data from Atlantic Canada, to develop maps showing the areas of different levels of soil loss (as contour lines) from water erosion.

Soil acidity levels were measured on a provincial level by Coote *et al.* (1986). The authors were able to categorise the regions studied into different classes of potential impacts using a database consisting of nitrogen (fertilizer) sales, crops cultivated, amount of nitrogen

[98] Modelling techniques such as the Universal Soil Loss Equation (USLE) and the Wind Erosion Equation (WEE).

fertilizers applied and acid rain depositions. The amount of fertilizers applied was obtained from the Fertilizer Institute of Canada, and varied according to regions and crops planted. The values of acid rain depositions were derived from the Canadian Network for Sampling Precipitation (CANSAP) database.

There have been some field experiments to measure the overall effect of compaction on yields of grain and forage crops in Quebec. Mckyes *et al.* (1979) found that an increase in soil bulk density of 0.1 to 0.15 tons/cubic metre above the optimum for plant yield, resulted in a yield loss of 0 to 30%, depending on the crop and soil type.

In Quebec, Tabi *et al.* (1990) of Quebec's Ministry of Agriculture, published a detailed study on the extent and causes of agricultural land degradation for the 12 agricultural regions of the province[100]. Based on the analysis of an extensive collection of field samples, the study listed the areas of land affected by each of the types of degradation processes. However, these figures were based on lands solely involved in monoculture cropping since Tabi *et al.* (1990) assumed that these lands were the most susceptible. Their data, therefore, does not cover all parts of, or impacts in the province.

Since 1991, the Soil Inventory Section of the Land Resource Research Centre at Agriculture Canada has been publishing detailed maps of soil landscapes in Canada. The maps are divided into unit areas called polygons with distinct sets of soil attributes or characteristics. These include soil type, slope, depth, water table, depth of compacted layer and others. The information is made available in either printed maps with a scale of 1:1 million or in electronic formats at the Canadian Soil Information System (CANSIS) database. The latter database has additional useful information such as nitrogen content and pH of the upper 15 cm, vegetation cover class for each polygon. This information can be used by researchers to determine areas with actual or potential soil degradation problems such as salinity, (susceptibility to) erosion and compaction, in addition to other planning

[99] Dr. Guy Mehuys is among the leading soil scientists in the province. He is currently a professor at McGill University, Ste. Anne de Bellevue, Quebec.
[100] Agricultural regions in the Province of Quebec have since been increased to 18.

usage such as optimal land use assessment, census or even for other governmental policies (subsidies, crop retirement plans, etc).

The increasing efforts by Provinces and the Federal Government to assess the extent of land degradation in Canada in general, and Quebec in particular, reflects the increasing importance of this issue. Consequently, these efforts have helped to advance the available knowledge and have filled many gaps. However, most of the generated estimates have wide confidence intervals. This is justifiable since the quantitative assessment of degradation issues is a difficult process. Additionally, the areas studied are very large and several methodologies were used.

Despite such difficulties, Crosson (1982) noted that attempts to determine the extent of soil degradation would be necessary to demonstrate a benefit to soil conservation. Furthermore, the estimation of the monetary value of land degradation would help to justify expenditures to prevent soil degradation (Anderson and Knapik, 1984).

5.1.3. Estimates of Land Degradation Costs in Quebec

Few studies have been done on the economic valuation of soil degradation in Quebec. Agriculture Canada (1985) and Environment Quebec (1988) have published estimates of these costs, but they did not show any detailed explanation of their methodologies, unlike Mehuys (1984) and Fox and Coote (1986) whose work included a detailed explanation of their valuation methodologies. Their findings are discussed in the next sections. To this date, the study of Fox and Coote (1986) remains the most comprehensive.

5.1.3.1. Soil Erosion

The impact of erosion on yield on the flat lands of Quebec was insignificant (Mehuys, 1984). However, on hilly areas, Mehuys estimated the cost of yield reduction to be around \$5.25 million per year. The total (on and off-farm) annual costs of wind and water erosion in Quebec was estimated at 10.5 millions. Agriculture Canada (1985) and Fox and Coote (1986) had different estimates for water and wind erosion: \$5-\$17 and \$2 millions, and \$14.4-\$17.1 and \$2.24 millions, respectively. The costs of water and wind erosion on vegetable crops (including potatoes) were \$9.74 and \$2.14 million[101], respectively (Fox and Coote (1986). These estimates were based on lost yield values (due to change in yield quantity and quality) as well as on costs of fertilizers and corrective cultural operations.

Fox and Coote (1986) concluded that the total impacts of water erosion are higher than that of wind. This is expected since wind affects a smaller area. On a per hectare basis, they calculated a cost of \$414/ha from water versus \$163 from wind). In comparison to the United States, soil erosion on a per hectare basis is more costly in Quebec. The former was estimated at about \$34.73 (in 1989); however, the total erosion costs and area affected are much larger in the USA. (Alt *et al.*, 1989). Unfortunately, there are no recent comprehensive studies about erosion in Quebec beyond these mentioned above, although there were few limited studies on selected watersheds in the province (e.g. Dissart *et al.*, 2000).

5.1.3.2. Soil Compaction

It was estimated that soil compaction would reduce yields by 3% on sandy soils, 16% on loamy soils, and 25-30% on clayey soils, for all the studied crops in Quebec, at a total cost of \$30.45 million (Fox and Coote, 1986). The losses for vegetable crops (including potatoes) were 10-30-50% (for different soil types) in the St. Lawrence region, at an annual cost of \$10.75 million. The authors based their estimates of yield losses on group meetings and questionnaires to farmers and agriculturists in the regions studied. It should be noticed that this cost is more than the combined effects of erosion and acidity in the province.

Based on the estimates of Mckyes *et al.* (1979)[102], Mehuys (1984) assumed an average yield reduction of 15% to determine the total costs of unrealised yield for all crops in Quebec. This was equivalent to \$99.9 million per year (Mehuys, 1984). This figure differs

---

[101] Fox and Coote (1986) noted that the yield reduction for vegetables in the St. Lawrence region is expected to range between 15 and 40 percent on moderately and severely eroded soils, respectively (When no extra fertilizers are added to compensate for yield loss).

[102] An increase in bulk density of 0.1 to 0.15 ton/cubic meters above the optimum (for yield producing of a certain crop), yield is reduced between 0 and 30%.

from Agriculture Canada's (1985) estimate of $30-99 million. Since the latter did not describe its method and assumptions, a judgement can not be made.

4.1.3.3. Soil Acidification

Acidity costs have primarily been estimated based on the amount of equivalent lime (calcium carbonate) required to neutralize annual acidification (Coote *et al.*, 1981; Fox and Coote, 1986; Mehuys, 1985). The authors did not consider the impact of acidity on yield. Mehuys (1984) reported that the estimation of associated yield change was difficult since the change in soil pH, and consequently the impact on yield, differs depending on the type of fertilizers applied and kind of soil. Furthermore, since correction for acidity is relatively easy (compared to other degradation effects), farmers try to maintain their soils at optimum pH level, at all times, and do not have to bear the associated yield reductions. Consequently, the costs of added lime would reasonably reflect acidification costs, mainly because it represents the costs of the followed remedial measure (Mehuys, 1985). The review of literature clearly indicates that the usage of the Corrective Cost approach was more common than the Change in Productivity (Dose-Response) method.

Estimates of the quantity of limestone needed can be quite variable. Coote *et al.* (1981) estimated that approximately 51 kilograms/hectare are required to neutralize the annual acidification caused by fertilizers. However, as leaching and nitrification vary, the amount of lime depends on the crops produced (reflects absorption efficiency and need), type of nitrogen fertilizer applied, and soil texture. Mehuys (1984), had different estimates. He reported that between 1.5 to 4.5 tonnes need to be applied per hectare every five years. At $18/tonne, this would be equivalent to $3.15 per hectare over five years, or an annual cost of $4.14 million for the whole province since 230,000 tonnes are needed. De Grandmont (1982) believed that two tonnes/hectare are needed every five years.

Fox and Coote (1986) believed that the annual cost of lime needed to neutralise total acidity on a provincial level was $2.672 million. Of these, $1.611 million were due to fertilizers effect, and the remaining were due to natural effects and acid rain. There was no estimate for the impact on land producing vegetables. However, if the average cost per hectare of all crops ($2.54) was used for the area planted with vegetables in Quebec, annual costs to vegetable producers would then be around $1.53 million. Based on the assumptions used, the figures of the last two studies are thought to be more realistic than that of Coote *et al.* (1981).

5.1.3.4. Soil Salinization

There appears to be no estimates of the extent or costs of yield reduction due to soil salinization, since this was a minor problem in Quebec.

5.1.3.5. Summary of on-Farm Land Degradation Impacts

Fox and Coote (1986) reported that land degradation in Quebec was equivalent to about $66 million annually in direct and indirect damages. Agriculture Canada (1985) and Environment Quebec (1988) had higher estimates; $77.5 and $114 millions, respectively. These values are listed in Tables 5.1 and 5.2. The latter table shows these costs in 1997 dollar values[103] in order to facilitate comparison. It should be noted, however, that these figures represent the degradation of their respective years and not that of 1997. In reality, the degradation costs of 1997 might be much higher than the tabulated figures.

Table 5.1: Summary of Land Degradation Costs in Quebec (in Million Canadian Dollars)

Estimates of	Compaction	Water erosion	Wind erosion	Acidification	Off-farm impacts	Total costs
Mehuys (1985)	99.9	5.25	1	4.1	5.25	115.5
Agriculture Canada (1985)	30-99	5-17	2	N.A.	N.A.	77.5 (Avg)
Fox & Coote (1986)	30.45	14.4-17.1	2.24	2.67	14.9	66.01 (Avg)
Environment Quebec (88)	N.A.	N.A.	N.A.	N.A.	N.A.	114

Table 5.2: Summary of Land Degradation Costs in Quebec (in Million 1997 Canadian Dollars)

Estimates of	Compaction	Water erosion	Wind erosion	Acidification	Off-farm impacts	Total costs
Mehuys (1985)	138.34	7.27	1.39	5.67	7.27	147.00
Agriculture Canada (1985)	89.32	15.23	2.77	N.A.	N.A.	107.32
Fox & Coote (1986)	41.20	21.30	3.03	3.62	20.16	89.31
Environment Quebec (88)	N.A.	N.A.	N.A.	N.A.	N.A.	144.55

*** Prices were adjusted using the Farm Input Price Index**

103 These figures were transformed to 1997 values using the Farm Input Price Index.

Based on Fox and Coote's estimates, the total annual on-farm costs of soil degradation on the areas planted with vegetables in Quebec were \$10.75, \$7.39, \$2 and \$1.53 million due to the effects of compaction, water and wind erosion[104], respectively. The authors did not report any costs for acidity, but it could be approximated at \$1.53 million [105]. The combined effects were valued between 2.4 and 3.2 percent of the on-farm operating costs (Fox and Coote, 1986). The same authors noted that additional costs of time, machinery and labour, as a result of degradation by erosion and compaction, could be added to the total bill. This could be safely assumed to be an additional 5% of the costs of production on severely eroded soils.

5.1.3.6. Off-Farm Land Degradation Impacts

As noted earlier (Chapter 2), the analysis of off-farm impacts associated with land degradation in this study consist mainly of the physical impacts caused by eroded soil. These include the sedimentation of waterways (rivers, basins, canals, drainage ditches) and physical damage to neighbouring fields (sedimentation, gullies, etc.). Other forms of (on-farm) soil degradation are believed to have little or no off-farm impacts (Chapter 2). The impacts of agricultural chemicals will be considered under the water pollution section.

It is believed that off-farm impacts in Quebec are at least as significant and costly as on-farm impacts (Mehuys, 1984; Fox and Coote, 1986). According to the National Research Council (1986), experts considered the effects of erosion on water resources to be greater than its potential effects on agricultural productivity, costing two to eight times more than the impact on productivity (USDA, 1987).

Off-farm costs (involving direct use values) usually include the sum of repair (for structural damage) and maintenance costs to channels, ditches, reservoirs and neighbouring fields, in addition to lost revenues due to reduced recreational activities and fish catch in affected regions. In some cases, sediments may also increase municipal water treatment costs

[104] Fox and Coote noted that the effects of wind erosion varied from one year to another thus affecting economic costs.

[105] This is reached by multiplying the average acidity costs per hectare by the total area of vegetables.

(Ribaudo and Hellerstein, 1992). Sometimes, the estimates of preventive/defensive costs, can be used as a proxy, although this may well underestimate the full value of damage that is expected to occur if no measures were taken, or if defensive measures do not fully prevent the damage. As mentioned in Chapter 3, changes in defensive expenditures will reflect the marginal WTP for improved environmental quality, with WTP acting as a proxy for the value of these costs. If a cause-effect relation can be defined then the dose-response method can also be useful.

Unfortunately little information is available to date on off-farm damage from soil erosion in Canada. To determine the off-farm economic impacts of soil erosion in Quebec, Fox and Coote (1986) extrapolated the results of a study done in the United States by Clark *et al.* (1985). These estimates[106], attributed mainly to reduced water quality and increased flooding, were valued at $14.9 million per year. The authors noted, however, that since the parameters needed to calculate off-farm costs are usually site- specific, the above figure was only a rough estimate. Mehuys (1984) reported that such costs were in the range of $5.25 millions in Quebec. Agriculture Canada (1986) calculated this cost under Canadian conditions to be $46/hectare of row crops for an equivalent total of $125 millions in Canada. Fox and Dickson (1990) estimated the costs of sediment effect on the value of freshwater angling, on the maintenance costs of roadside ditches and on municipal water treatment costs for three watersheds in south-western Ontario. The costs ranged from $6.34 to $100 per hectare per year for the three watersheds, depending on the production scheme, with the no till practice showing the least cost and the fall moldboard ploughing showing the highest figures. The average figure reported in the study was $38.9 per hectare.

Ribaudo (1989) of the Economic Research Service at USDA has presented a comprehensive estimate of the off-site costs of soil erosion for different areas in the United States. Assuming fairly similar variables between the north-eastern regions of the United States and Southern Quebec, findings can be transferred with some modifications. Ribaudo

[106] The extension considered that the same damage occurred per a hectare of land of row crops.

estimated off-farm costs at US$7.06 /ton of eroded soil (1989 dollars). This figure is approximately equivalent to US$146/ hectare (1989 dollars).

Due to lack of sufficient local information, it is difficult to determine with certainty the extent of loading of suspended solids from farming activities into the Saint Lawrence River (SLR), but it is believed that this problem may become of increasing importance in the near future in Quebec (Environment Canada, 1999).

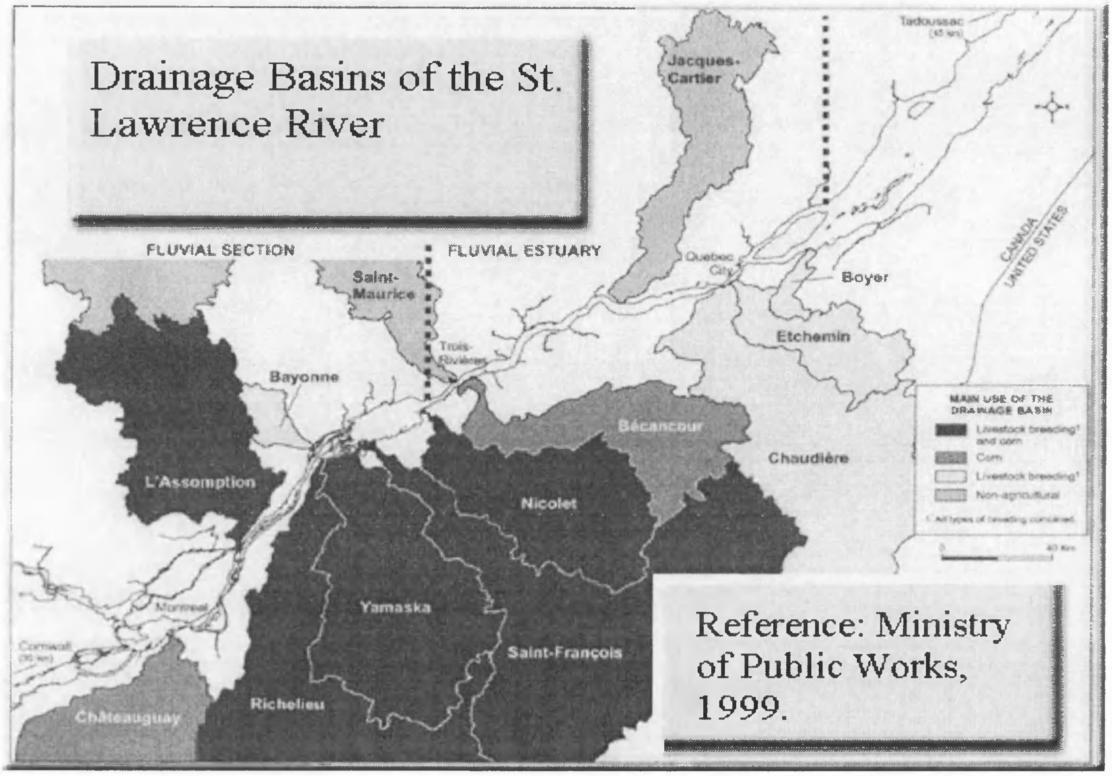
5.1.4. Water Pollution by Agricultural Chemicals in Quebec: Physical Measurement

The Saint Lawrence River (SLR) is the main body of water in the province. Water originating from the Great Lakes traverses part of the provinces of Ontario, Quebec and New Brunswick for a distance exceeding 1200 kilometres and eventually pours into the Atlantic Ocean. Most of Quebec's population is concentrated along the length of its shores and get their drinking water from it. At the same time, since the main agricultural activity in Quebec is located in areas adjacent to the Saint Lawrence River, most of the over-fertilisation and pesticide contamination problems occur in the river and, specifically, in the southern slopes of the river and its tributaries (Environment Quebec, 1988).

The St. Lawrence River has five main and nine secondary water masses associated with its main tributaries. The main water masses are: a) the waters of the Great Lakes (upstream and downstream of Montreal); b) the waters of the Ottawa River, c) mixed waters of the Ottawa River and l'Assomption rivers and the Great Lakes east of l'Assomption River (Ottawa-north shore mix), d) mixed waters of the south shore tributaries and the Great Lakes (Great lakes-south shore mix) and e) the waters of the Quebec City region. The nine secondary water masses are those of the Saint-Louis, Chateauguay, L'Assomption, Richelieu, Yamaska, Nicolet, Saint-Maurice, Becancour and Jacques-Cartier rivers (Environment Canada, 1996).

Hydrologically, Environment Canada (1999) divided this area into 13 drainage basins, namely La Chaudiere, Yamaska, L'Assomption, Etchemin, Richelieu, Saint-Francois, Nicolet, Bayonne, Boyer, Becancour, Chateauguay, Jacques-Cartier and Saint-Maurice rivers. These drainage basins are shown on the map in figure 5.2. For the region under study in the research (Monteregie), the following drainage basins are included: Chateauguay, Richelieu and Yamaska.

Figure 5.2: Drainage Basins of the St. Lawrence River



Contamination by agricultural chemicals is, potentially, a serious problem affecting both the surface and ground water in Quebec. It is believed that chemicals reach water bodies by water run-off, water discharges (& drainage), eroded sediments or seepage through the soil into groundwater. However, it is quite difficult to establish an accurate relation between the agricultural activity around the SLR and the state of environment of the river. These difficulties arise from the variable and diffuse nature of agricultural pollution, vastness of the agricultural area, the hydrodynamics of the SLR and its tributaries, soil types and usage, topography and production techniques, among other factors. Therefore, the figures presented in this section are to be considered preliminary estimates/observations, which may not completely reflect the amount of environmental damage or its effects on the ecosystem.

Environment Quebec relied on chemical analysis of water samples to estimate levels of contamination in various water bodies over the period from 1988 to 1992. Environment Canada complemented such work and produced an extensive report on the St. Lawrence River (SLR) ecosystem in 1996, covering various chemical, physical and biological aspects. The latter report evaluated water quality from three perspectives: direct human consumption, water-contact recreation and aquatic-life support. Some of the impacts considered were not fully caused by agricultural activities. Environment Canada (1999) published a more specific report on the impacts caused by agricultural activities on the SLR. This was the result of a joint effort by the Federal and Provincial Ministries of the Environment. It is believed that this report is the most comprehensive to date. In addition, an extensive amount of literature exists on evaluating fertilizers and pesticides contamination in various parts of the SLR and its tributaries. The relevant results of these studies will be summarised in the next section.

In Quebec, limited contamination modelling was done. Enright and Madramootoo (1990) and Wiyo (1991) used the CREAMS Model; Masse and Prasher (1989) with GLEAMS; Villeneuve *et al.* (1987) and Banton *et al.* (198?) with VULPEST. However, the models were used on small areas (fields or watersheds) because the model parameters account for uniform conditions, which are unlikely to be found for large areas.

Lamarche (1992) studied the quality of water for human consumption in the river and its basins based on continuous monitoring from 1978-1988. To isolate the effects of agricultural contamination, he classified the areas into three divisions for both fertilizers and pesticides based on the expected expenditures on these items, which is mainly a function of the crops produced in these areas.

In another qualitative study that covered the whole province, McRae (1989) was able to identify areas of potential pesticide contamination of ground water in Quebec by defining areas vulnerable to leaching according to soil characteristics such as, soil texture (sandy group), slope gradient (1-9%), depth to water table and surface formation. The soil information was obtained using maps generated by the Generalized Soil Landscape Mapping (GSLM) project, which divided the provinces into numbered polygons of uniform soil attributes. The result was the generation of maps with a scale of (1:2,000,000) showing polygons of potential contamination. Although organic soils were not studied and ground water recharge rates were not accounted for, it is believed that this work gives a good indication of the extent of this problem.

It should be noted that this research only considers the value of water from the human consumption and domestic usage perspectives. It is quite difficult to estimate effects of agricultural pollution on recreation and aquatic life since the available data is almost non-existent[107] or insufficient. A summary of the findings of the above studies is presented in the next section.

5.1.5. Estimates of Chemical Pollution in Water

Environment Canada (1996) performed chemical analysis of water samples for the five major water masses of the St Lawrence River (SLR) over the period extending from 1985 to 1993. It concluded that the average concentrations of dissolved nitrates (NO3-NO2) and phosphorus fertilizers in the (research) relevant water mass (Great Lakes-south shore mix), estimated at about 0.32 and 0.052 mg/litre, respectively, were below the human consumption-safety threshold for nitrates but higher for phosphorus[108]. In comparison, the average nitrates concentration in North America was 1.0 mg/litre, and 3.7 mg/litre in Europe. Some rivers in Quebec, however, have much higher pollution levels (than the provincial average). Cluis *et al.* (1990) reported that NO2-NO3 levels have increased at an estimated 0.02 mg/litre per year between 1978 and 1988. Environment Canada (1999) reported that total nitrogen and phosphorus loads attributed to farming activities were

[107] Few studies exist on levels of eutrophication in some lakes in Quebec (e.g. Environment Quebec, 1988, 1992). However, these studies do not reflect the overall situation.

[108] The maximum allowable levels for safe human drinking is 40 mg/litre for nitrates and 0 mg/litre for phosphorus. Total phosphorus levels exceeding 0.030 mg/litre promote excessive growth of aquatic vegetation where water currents are slow, and this affects recreational activities.

estimated at 73% and 75%, respectively, of the total flow at the mouth of the Yamaska river.

The criteria for safe water consumption was occasionally exceeded (for 2 to12% of the time) for ammonia nitrogen at the mouths of the Yamaska and Richelieu rivers between 1995 and 1998. Similarly, the criteria for the protection of aquatic life was exceeded by more than 85% for total phosphorus levels in the Yamaska and Chateauguay rivers and between 20-50% in the Richelieu river for the period from 1989-1994 (Environment Canada, 1999). The trend may increase due to the saturation of soil with phosphorus in the farming basins.

Environment Canada (1999) estimated the surplus amount of nitrogen and phosphorus fertilizers spread in each of the drainage basins in Quebec. For the three basins under study in the Monteregie area, these were estimated at 37.26, 43.18 and 99.5 kg/hectare for nitrogen and 7.81, 9.14 and 22.32 kg/hectare for phosphorus in the Chateauguay, Richelieu and Yamaska rivers, respectively.

As for pesticides, the quantities of pesticides applied in the region have been steadily increasing since 1970 (Statistics Canada, 1991). Environment Quebec (1992) estimated that about 2,500 tonnes of pesticides were introduced into the environment in 1986. Eighty five percent of these originated from the agricultural sector. The numbers have increased with time. Environment Quebec (1999) estimated that approximately 2,732,751 kg of active ingredients, or about 80.8% of the pesticides sold in Quebec in 1997, containing 153 active ingredients, were used in agriculture. Half of the agricultural pesticides are used on corn (Environment Canada, 1999).

After testing for pesticide contamination in several rivers[109] located in areas of intensive agricultural activity, between 1980 and 1991, Environment Quebec (1992) found that several Organo-chlorine pesticides, such as DDT and HCB, were present in low

[109] Samples were taken from the following rivers: Yamaska, Saint Francois, Richelieu, Chateauguay, L'Assomption, Saint Regis and la Tortue.

concentrations that do not endanger aquatic life. Unfortunately, other pesticides such as atrazine (herbicide), diazinon (insecticide), lindane and endosulfan (insecticides) existed at dangerous levels. Conclusions about DDT and its metabolites were confirmed by Pham *et al.* (1996) who, after studying water samples from the SLR and four of its main tributaries between August 1990 and November 1991, found that DDT was present in average yearly concentrations that ranged between 0.3 ng/Liter and 3.02 ng/Liter, depending on the month of the year. Although DDT was banned in Canada in the early 1970 s, traces can still be found due to its highly persistent behaviour, which allows it to accumulate in lipids, and hence in animals and plants. DDT transmitted from the tributaries is believed to have originated from the melting of the snowpack and from the run-off of contaminated soil particles from the watersheds.

Quemerais *et al.* (1994) concluded after analysing samples of water from various stations along the St. Lawrence river in 1991 that polychlorinated biphenyls (PCB), chlordane, hexachlorobenzene (HCB) and hexachlorcyclohexanes (BHC) were detected in various quantities, and their mean concentrations in the river were equal to 1, 0.32, 0.01 and 0.06 ng/L for the previously listed pesticides, respectively. While these values are relatively small and are within the accepted threshold of human safety, the concentrations varied in different regions of the river and with the season. PCBs, which were restricted in 1980 in Canada, and BHCs[110]concentrations have shown a decreasing trend since the late eighties, while HCBs and chlordane (restricted since December 1985) have remained relatively constant since 1986. PCBs are still the major organochlorine contaminants in the river.

Environment Canada (1996) reported that three substances-chlordane, DDT and its metabolites[111]and endosulfan (insecticides)- were detected in the SLR in the studied water mass, at levels equal to 0.484, 1.484 and 0.006 ng/litre for the three substances, respectively. While the levels of the first two compounds were within the safe human

[110] BHCs are hydrophilic substances, i.e. highly water soluble and reach water bodies through leaching and run-off. Hydrophobic substances, such as PCBs, chlordane and HCB usually reach water bodies with eroded/ suspended particulate matter. Chlordane and PCBs are very persistent chemicals and have high bio-accumulation potential.

[111] DDT was completely banned since the 1970's but it is a highly persistent chemical.

consumption levels, the third was not[112]. Additionally, herbicides such as atrazine, cyanazine, simazine and metolachlor and other pesticides such as lindane and endosulfan were detected at low levels in the St. Lawrence River, but it is believed that these originated mainly from the Great Lakes region (Environment Canada, 1999)[113].

Giroux *et al.* (1997) concluded after examining samples of tributaries' water in areas where corn was mainly produced between 1994-1995, that average concentrations of chemicals used in the production of corn in water were, in general, within the threshold for safe human consumption. However, the safe criteria were exceeded in 12% of the samples for atrazine and cyanazine. Additionally, criteria for safe usage of water for irrigation were frequently exceeded by herbicides such as atrazine, simazine and metribuzine.

Environment Canada (1999) concluded after extensive sampling of drainage basins that the quantity of active ingredients was 2.7, 2.4 and 2.1 kg of active ingredients (a.i.) per hectare for the three relevant river drainage basins in Monteregie, namely Chateauguay, Richelieu and Yamaska, respectively. It is believed that this study is the most accurate to date.

These findings should be interpreted with caution as the potential impact on humans is still not fully understood and the criteria do not take into consideration synergistic or antagonistic effects of mixtures of diverse substances. Information on the persistence of these pesticides in water is still inadequate. Furthermore, average estimates from sampling stations may hide the high concentrations present in non-sampling locations/ sections of the rivers. Indeed, while pesticide and fertilizer contamination may be at acceptable levels (except for phosphorus) in the main St. Lawrence River, agricultural contamination is higher and more potentially harmful in the river's tributaries. It should be noted that the studied water masses have other industrial contaminants and urban effluents that prevent it from being considered safe for human consumption.

---

[112] Levels for safe human consumption are 7000, 30000 and 0 ug/litre for chlordane, DDT and its metabolites and endusulfan, respectively.

As for ground water, which is often used for drinking and domestic use in rural areas of the province, Environment Quebec (1988) reported that in general, the ground water was of good quality and required little or no treatment. However experiments in the following years showed that this was not an accurate statement. In 1992, Environment Quebec reported that 15 pesticides[114] have been detected in ground water. Of these, levels of aldicarb exceeded the threshold for safe drinking standard in many wells. Most of the contaminated cases (15 pesticides) were found in the Montreal-Lanaudiere regions. Environment Quebec believed that most cases of ground water contamination have been related to potato and corn farming. Although aldicarb has been removed from the market, traces are still being found due to its slow degradation. It is believed that traces would take about five years to disappear (Environment Quebec, 1992).

Giroux (1995) concluded after examining samples of ground water in areas of intensive potato production between 1991 to1993, that all of these regions suffered from nitrates and pesticides contamination at various levels, some of which exceeded the safe drinking level for the insecticide aldicarb and nitrogen nitrates. In addition, the herbicide metribuzine exceeded the irrigation quality threshold in many samples. Many other pesticides were detected at lower levels in 50% of the samples collected. Giroux *et al.* (1997) found traces of triazine and nitrates in the ground water of some drainage basins where corn is the major produce (basins of Chateauguay, Richelieu, Yamaska, Nicolet and Becancour). Concentrations were below the safe drinking threshold for triazines (5 ug/Liter) but that of nitrogen-nitrates exceeded the safe level of 10 mg/Liter for 3% of the samples.

In summary, it can be concluded from the reviewed studies that although the overall level of chemical contamination, in both the surface and ground waters, has not reached highly dangerous levels yet, the frequent discovery of contamination in the collected samples is worrying and indicates an increasing risk of potential problems for humans when water is used for drinking or irrigation. The problems may become more serious in the future since

[113] Environment Canada (1999) believed that only 7% of atarazine and 30% of metolachlor loads originated from the SLR tributaries.

[114] These pesticides included metribuzine, carbofuran and others (Environment Quebec, 1992).

the level of chemical application has been steadily increasing, and since many of the chemicals found have strong persistence in water. For these reasons, agricultural chemical contamination should be considered as a potentially serious problem that ought to be closely monitored.

5.1.6. Costs of Water Pollution in Quebec

Only a single study, published by Environment Quebec (1988), has so far been undertaken on the economic costs of water pollution in Quebec. The study reported that total expenditures on water treatment in the province between 1978-1988, were, on average, equivalent to 175 million dollars annually (excluding pulp and paper industries). Of this amount, about 100 million dollars could be attributed to agriculture. There are also some municipal publications showing water treatment costs per cubic meter for various municipalities across the province.

5.1.7. Studies of Agriculture's Health Impacts in Quebec

In Quebec, the collection of physical data on health incidents related to the use of agricultural chemicals is a difficult process. Data is sparse and is not centrally collected. No single authority in Canada or even in Quebec can claim that it has a complete record of all incidents. This is understandable for at least two reasons: first, most hospitals keep their records confidential and do not share them, and second, toxicity symptoms, in many cases, may be incorrectly diagnosed since the testing is rarely specific to agricultural chemicals despite the existence of relevant techniques. (Dr. D. Irwin[115], personal communication, 1994). There are, however, some studies performed by researchers in various faculties of medicine, but these are case-specific.

It is believed that the best source of information can be obtained from anti-poison and toxicity centres across Canada (and Quebec in particular). These centres run a hot-line service whereby they offer appropriate advice to the public on suitable actions in response to pesticide-related accidents. The centres keep records of all communications (with the

[115] Dr. Irwin is a toxicologist working in the Lakeshore Hospital, Pierrefonds, Montreal, Quebec.

public) including the type and number of toxicity incidents as well as actions advised. The data are occasionally published in statistical journals.

In 1997, the Anti-Poison Centre of Quebec (APC) received 105,276 calls of which 57,974 were related to toxic substances, including medical, commercial, industrial and domestic incidents (APC, 1998). Over 90% of the incidents were involuntary, half of which, affected children who were less than five years old. Of the 1527 pesticides-related inquiries, 61.3% were attributed to insecticides, followed by insect-fumigants (14.1%), rodenticides (11.2%), herbicides (8.1%) and 5.3% for other kinds of pesticides.

The APC also reported that in 1997, there were 21 incidents due to farm applications in Quebec, of which seven cases went to the hospital emergency for treatment. Fortunately, there were no fatalities due to pesticide contamination or exposure reported. No data existed for off-farm accidents, e.g. from eating contaminated food.

5.1.8. Studies on Farm Employment

The Quebec Ministry of Agriculture (1998) reported that the agri-food sector employed 389,100 people in 1996 or about 11.9% of the provincial workforce. Of these, some 75,000 were on-farm jobs. Family labour accounted for 68,000 jobs and the rest were hired labour. The total number of on-farm workers increased to 124,000 in peak times, when seasonal workers were hired. Women constituted 35% and 27% of the family and hired labour forces, respectively. More details on the above figures are presented in Table 5.3.

The average wage rates for hired agricultural labour, doing general farm work, in Quebec was C$8.72 per hour in 1997 (Statistics Canada, 2000), which is slightly higher than the minimum rate of C$6.75 per hour.

Table 5.3: Agricultural Farm Labour Force in 1996

	Men	Women	Total
Family Labour			
Owners	35,071	12,132	47,203
Spouses	1,159	9,015	10,174
Children (16 & over)	7,895	2,746	10,641
Total Family Labour	***44,125***	***23,893***	***68,018***
Hired Labour			
Permanent	5,630	1,653	7,283
Seasonal	35,114	13,557	48,671
Total Hired Labour	***40,744***	***15,210***	***55,954***
Total	**84,869**	**39,103**	**123,972**

Source: Quebec Ministry of Agriculture, 1998.

It is believed that 60% of the farm labour force worked on dairy and horticultural farms while 11% worked in beef and 8% in grain-producing farms (Quebec Ministry of Agriculture, 1998). In the Monteregie region, there were 7,500 crop-producing farms employing 19,400 full time labours in 1997. This makes an average of about 2.59 full-time workers/farm. There may exist additional statistics on farm employment at the federal and provincial Ministries of Statistics, Labour and Agriculture, but the one cited above is believed to be the most relevant.

However, although on-farm employment figures may not be as large as that of other economic sectors in the province, the farming sector remains the main provider of employment in rural areas. When related jobs in processing, marketing and retail are considered, the figures and economic impacts become quite significant to the economy.

5.1.9. Costs of Health Impacts and On-Farm Employment in Quebec

Since literature on these two issues, in general, and their impact on the provincial and Canadian economy, in particular, is almost non-existent, a methodology is suggested in Chapter Five to place some monetary value on these impacts. There is however, a single study by Thomassin (1992), who used an input-output model to estimate the impact of an increase in the final demand for primary agricultural products and (processed) food products on the Canadian gross domestic product (GDP) at factor cost[116] and employment. Using the Statistics Canada medium level input-output model, which contains 100 commodities and 50 industrial sectors, Thomassin concluded that a $100 million increase in the final demand for primary agricultural products (at farm gate/producer prices) would generate an increase in industrial output by $185.4 million, GDP at factor cost by $85.7 million and employment by 2,850 jobs. A similar increase in demand for food products would result in an increase in industrial output by $205.6 million, GDP at factor cost by $83.6 million and employment by 1,848 jobs. The larger increase in employment generated by an increase in the demand for primary products was explained by the fact that the agricultural sector includes paid and unpaid self-employed farmers. If unpaid labour were not included, then the figures for newly generated employment would decrease to 1,456 and 1,359 for the primary agricultural and food sectors, respectively.

As this study has covered conventional produce only, a similar increase in the demand for organic agriculture is expected to create a larger number of employment opportunities since organic agriculture is more labour intensive.

[116] GDP at factor cost, or value added, is equal to total sales (gross output) less inputs of goods and services (intermediate inputs) that were purchased (Thomassin, 1992).

CHAPTER 6
RESEARCH METHODOLOGY

6.1. Introduction

The applied methodology is discussed in this chapter under two main headings. The first heading describes the design of an extended CBA along with suggested extensions to better accommodate sustainable development values. In the second, there is a discussion of the physical and monetary techniques to be used for the evaluation of relevant social and environmental impacts.

6.2. The Cost-Benefit Analysis Technique

As discussed in earlier chapters, the CBA technique is a monetary appraisal technique that involves the quantitative evaluation of a project's net economic benefits. Using a discounting process, costs and benefits of different time periods are transferred into a common temporal basis of measurement, by dividing them by a compounded interest rate that reflects an appropriate opportunity cost of money, and are then compared. If the discounted benefits exceed the discounted costs, then the project may initially be considered as a potentially worthwhile one, unless there are other considerations or constraints, such as a certain capital payback period, financing or political constraints.

In this research, the evaluation analysis will mainly focus on two criteria: The Net Present Value (NPV) and the Benefit-Cost Ratio (B/C), also called the Profitability Index (PI). Other criteria such as the Internal Rate of Return (IRR), Accounting Rate of Return (ARR)[117] and Discounted Payback Period (DPB) will be often mentioned in the discussion of results[118].

The NPV represents the sum of the discounted future stream of annual net returns. It is expressed mathematically as follows:

---

[117] Also called the Average Accounting Return (AAR) or Return on Investment (ROI).

[118] These two techniques have some weaknesses. The main weakness of the ARR is that it does not account for the time-value of money. The DPB method does not consider what happens to projects beyond the capital recovery period, and therefore the analysis is deemed incomplete.

$$NPV = \sum_{t=0}^{n}\left[\frac{(B_t - C_t)}{(1+r)_t}\right] = \sum_{t=0}^{n}\left[\frac{NR_t}{(1+r)^t}\right] \quad \text{Equation 6.1}$$

Where

Bt = Benefits at time t
Ct = Costs at time t
NR = Net returns
r = Discount rate
t = Time frame, i.e. year

Even in cash-accounting terms, net returns (NR), the numerator in the above equation, are not the same as the accounting profit, since the latter allows for interest expenses. In financial analysis, the used numerator is the net cash flow, which is equivalent to:

$$\mathbf{NCF = EBIT\ (1\text{-}T_c) + Dep.\ x\ T_c - I} \quad \underline{\mathbf{OR}} \quad \mathbf{NCF = (S\text{-}C\text{-}Dep.)\ x\ (1\text{-}\ T_c) + Dep. - I} \quad \text{Equation 6.2}$$

Where

EBIT = Earnings before interest & taxes
T_c = tax rate (corporate or applicable)
Dep.= Depreciation
I = Future investment (in working capital)
S = Sales or revenues
C = Operating costs

Projects are considered feasible if the NPV is greater than or equal to zero. An NPV of zero means that the project's net inflows were sufficient to repay the invested capital and had provided the required rate of return on the capital invested. A positive NPV, on the other hand, means that the flows generate an excess return[119]. A decision-maker usually selects the project with the highest positive NPV, if the projects compared are mutually exclusive. The NPV is the most commonly used method because it accounts for all cash flows over the life of the project and considers the time value of money.

[119] Excess return, i.e. over the required return or cost of capital. The excess is the NPV value.

The B/C or PI method represents the ratio of the discounted future stream of benefits over discounted future costs, and can be expressed mathematically as follows:

$$B/C = PI = \frac{PVbenefits}{PV\cos ts} = \frac{\sum_{t=0}^{n} \frac{IF_t}{(1+k)^t}}{\sum_{t=0}^{n} \frac{OF_t}{(1+k)^t}}$$ **Equation 6.3**

Where

PV = Present Value
IF_t = Inflows at time t
OF_t = Outflows at time t

A project is generally acceptable if its PI is higher than one. This ratio is mainly helpful in ranking projects by profitability, and it is usually used in conjunction with the NPV.

The Internal Rate of Return (IRR) is the rate which equates the present value of a project's expected inflows to the present value of its expected costs. The Discounted Payback Period, on the other hand, is defined as the number of years needed to recover the original investment from discounted net flows. The IRR and the DPB are briefly defined here due to their relevance to the future discussions and analysis. Additional details on the above equations or methods can be found in Brigham and Gapenski (1996), and Ross *et al.* (1999). Other parameters of the CBA are discussed in the sections that follow Section 6.3.

6.3. The Suggested Extensions

For CBA to better reflect the values of sustainable development in general, and sustainable agriculture in particular, the following steps are suggested. These steps, when taken, will help to address the concerns mentioned in the literature review.

1. **Widen the scope of analysis by internalising the associated social and environmental impacts:** The long-term environmental and societal impacts of production systems are to be considered as an integral part of the analysis, along with financial viability.

   Incorporating the values of (a project's) externalities into the analysis will ensure that all production costs are accounted for, and that any negative or irreversible damage will not pass unnoticed. This will draw attention to the significance of environmental and social impacts, and will emphasize the benefits of conservation and protection of resources. Furthermore, this approach will better reflect the multi-dimensional nature of the analysis, compatible with the nature of the issue under consideration. It should be noted that the success of this step depends on the appropriate evaluation of relevant physical and monetary externalities, which (often) remains a difficult process notwithstanding the recent developments in the field of environmental economics over the past few decades.

2. **Choose a lower-than-market discount rate:** such a rate would better reflect sustainability and help to promote conservation of natural capital. It would also help to achieve a better (and more equitable) distribution of costs and benefits between current and future generations.

   Despite arguments for zero discount rate discussed in the literature review section, the usual market criterion of a positive discount rate is used.

3. **Use a system of weights for various categories of impacts[120]:** weights, which are greater or equal to one will be assigned to various impact categories (economic, social

[120] There is an extensive discussion in the literature on the introduction of a distributive weighting system to reflect interests of groups with various incomes. This issue will not be considered in this research.

and environmental)[121], and will then be multiplied by the values of these impacts and summed[122] to give a cumulative figure (total weighted value). This will generally serve one or more of the following three purposes depending on the situation: 1) to reflect the relative importance of various impacts based on values assigned by the studied community, and therefore, help to ensure that the community concerns are integrated in the decision making and their objectives met[123]; 2) to permit the consideration of distributional effects among different groups, since CBA does not originally distinguish between who loses and who gains, thus safeguarding a community's optimal welfare[124]; and 3) to reflect the seriousness of specific existing problems. The seriousness depends on the difference between actual and sustainable resource use levels[125]. Therefore, the greater the gap, the larger is the weight and consequently the cost. The introduction of weights may also satisfy the concept of sovereignty of individual preferences over collective preferences with the collective value of the parts greater than their sum. This does not have to be at the expense of synergism and cumulative effects shown in ecosystems, as advocated by Hanley and Spash (1993). In this research, the focus will be on weights serving the first purpose, i.e. reflecting relative preferences.

Some economists (e.g. Ray, 1984) have argued against the use of such weights in the CBA analysis, suggesting instead, to leave it to the policy makers because it involves a value judgement and as it may deviate from efficiency criteria[126]. However, it is still believed that such weights will be helpful in emphasising sustainable development

[121] Weights can also be assigned to issues within a category and then added up.

[122] Using the Weighted Summation Technique.

[123] In this regard, weights can also be used to socially correct any economic values placed on environmental impacts.

[124] The differential weighing of impacts could insure that the social implications of a project, i.e. distribution of costs and benefits (wealth) among the society members (or even across generations) follows a pre-defined social welfare function or is in accordance with the criteria set by the policy maker to insure (intra and inter-generational) equity. Weights may also insure better distribution of costs and benefits if potential compensation (as per the Kaldor-Hicks criterion) is not done, either within the project framework or through governmental transfer payments.

125 The sustainable use level should be predefined and is usually case specific.

126 It is believed that politicians can better trade-off benefits against non-economic objectives.

objectives. Kirkpatrick and Lee (1997) also noted that there was no general consensus on how the weights should be calculated. While this is a valid argument, there are many ways to develop these weights. Usually, it can be done through public or expert surveys in the community where the analysis is concerned. More details on the development of weights are discussed in Section 6.6.

These suggested changes could provide policy makers and environmentalists with a more comprehensive and improved tool for decision making.

6.4. The Parameters of the Extended CBA

The parameters for the extended CBA analysis as well as other relevant factors are discussed in this section. These include:

1. Defining the scope of analysis.
2. Identifying relevant costs and benefits.
3. Identifying data sources and collection process.
4. Selecting the physical measurement techniques.
5. Identifying suitable monetary valuation techniques.
6. Determining the discount rate.
7. Devising the weighting system
8. Conducting the sensitivity analysis

6.4.1. Scope and Dimensions of the Analysis

The extended cost-benefit analysis will be applied to evaluate and compare the returns to organic and conventional vegetable production systems on a typical[127] vegetable farm in the province of Quebec. The farm is assumed to be of a comparable size (16 hectares) to the provincial average of vegetable farms with the dominant biophysical conditions of the region. It is located in the Monteregie area (Agricultural region no. 16) where most of the vegetable crops are produced in the province. Monteregie lies in the St. Lawrence lowlands where the main agricultural activity in the province occurs[128]. Visits to various organic

[127] It should be noted that organic farms are quite diverse. The term typical means here a widely present model. More details are presented in Appendix A.

[128] Most of the population of the province of Quebec lives in this region, and most (agriculture-related) environmental damage originates from farms located in the region.

farms across the province as well consultations with agricultural experts have helped to outline the most common practices in the province and a set of somewhat standard machinery. Information about production practices and machinery was used for the determination of budgets in this research. The crops under study include some of the main organic vegetables produced in the province. The same farm is assumed to produce conventionally a similar acreage of the crops. Additional details were derived from CREAQ publications, which outlines standard and common procedures/practices followed in the province as well as the associated production costs. These publications are based on a survey of many farmers, and are published on a regular basis. A detailed description of the farm characteristics is discussed in Appendix A. The two production systems will be evaluated using the conventional and the extended CBA analyses, and the results of both analyses will be compared.

The use of a (single) typical farm as the unit of analysis can be justified based on the following arguments. 1) The comparison of farming systems is generally a difficult and problematic area of research (Lampkin and Padel, 1994). Farms (even within the same farming systems) usually have a wide variation in variables such as farm location, farm characteristics, production and marketing methods, crop varieties used and managerial influences, to name a few. If the comparison of paired farms similar in size, location and type is not possible, then comparisons could be carried out using averages for groups of farms within each system as is done here. The latter comparison provides results that can be reasonably generalized, even though it may ignore some minor differences within the same group. The comparison should usually exclude exogenous and uncontrollable variables such as weather, management etc and focus on relevant endogenous variables. Such comparisons can serve as a basis for further detailed assessments. 2) The purpose of this work should be looked upon as an attempt to re-emphasize the fact that a different approach for project evaluation will result in different recommendations, and to provide some indication of the broad differences it will make. It also aims to demonstrate the application of the extended CBA rather than generate exact numerical results from the analysis; nonetheless, the attempt to place monetary values on impacts is carried as far as possible. 3) Considering a typical farm, as a unit of analysis may be more controllable and practical than doing the analysis on a provincial scale. A provincial level of analysis would require the aggregation of impacts over various areas with different biophysical conditions, which besides relying on a large number of assumptions, will require an extensive amount of data, some of which is not available. The farm approach uses a lesser number of assumptions and variables that need to be calculated, which is expected to produce results with reduced errors. At the same time, there can be no comprehensive guide to the characteristics of transition to organic on a provincial level to rely upon. Other reasons for not working on a macro level is that it is unrealistic to assume that all farmers in the province would transfer to organic production in the future, although it is not unrealistic to assume that a larger number of farmers would resort to more sustainable practices in the future. Additionally, a macro analysis would require the consideration of the impacts on overall prices, income, employment, as well as assumptions concerning consumption patterns, etc, which may be difficult to make given the nature and objectives of this research. Additionally, the evaluation of impacts on a micro-scale is a good exercise that can provide insight of expected outcomes when the analysis is later done on a larger scale.

The analysis will consider the social impacts of the farm activities. This societal perspective is a key issue since impacts are not restricted to the farm boundaries. Therefore the analysis will account for off-site social and environmental effects to the society in Quebec, in addition to the financial returns to a farm. A private view is obviously concerned only with private impacts, i.e. those impacts directly affecting the farmer and occurring within the farm boundaries, and the resulting decisions may not always be compatible with society's broader goals. Furthermore, the analysis will mainly focus on the direct use values for various variables since non-use values are more controversial.

The methodology used in this research, especially for environmental and social impacts, mostly follows a "top-down" approach in damage estimation, whereby, the analysis starts with regional data on damages and attempts to attribute part of that damage to the production practices in the typical farm.

The year of analysis for this study is 1997. This is because it is the most recent year for which (almost) complete data sets exist. Data for different years will be converted to this chosen base year using appropriate indexes.

The study will consider a medium time frame of 25 years. From a sustainability perspective, the longer the time frame of analysis, the better will the analysis be as far as portraying the potential impacts on future generations, thus helping to verify whether inter-generational equity objectives are served. However, in environment-related projects, uncertainties exist in many variables, and the use of a longer time frame could produce unreliable results[129]. While the appropriateness of such a timeframe may be debatable, a sensitivity analysis will be made considering various time frames (Section 6.7). There will be no attempt to consider the relevant impacts that extend or last beyond this time frame since there will be many uncertainties involved[130]. Impacts occurring outside the province, such as incidents from exported chemically contaminated food will be excluded from the analysis due to the difficulties in estimation.

6.4.2. Identifying Relevant Costs and Benefits

In this study, the focus will be on five priority or significant factors to reflect some of the impacts caused by conventional agriculture. These include land degradation, water pollution, (acute) human health impacts, rural employment and net financial revenues. While it is obvious that there are many other negative effects, these were excluded due to either difficulties in obtaining data, in making reasonable assumptions for the quantification of physical and monetary impacts, and due to the lack of previous impact studies. (A larger list of impacts is presented in Table 6.1).

The exclusion of some of the variables listed in Table 6.1 is not expected to severely affect the completeness of the analysis since the chosen factors highlight, or are themselves, some of the main issues and concerns. The analysis is still believed to provide a fairly

---

[129] The value of a resource, rate of use and the subsequent effect on environment may change in the future with levels of resource scarcity, pollution levels and concerns for the environment.

[130] Residual values are usually incorporated in the analysis in the last year using annuity values.

comprehensive assessment and comparison of both production systems. The following arguments can also be used to defend this choice:

1. To develop a comprehensive, yet concise list of key impacts to reflect sustainable practices is a difficult and controversial process and is still the subject of ongoing research by many governmental and non-governmental agencies[131]. At some point, subjective judgements have to be invoked.

2. Many of the effects and impacts are inter-related. The cause- effect relationships are often not well understood and the effects may take several years to show. Therefore, some impacts might reflect more than one variable. For example, certain health effects might take years to show and could be the result of inhaling chemical fumes and/or consuming pesticide-polluted water.

3. While there exists a vast variety of impacts, the analysis can be reasonably restricted to those that can be regarded as scientifically valid, representative of conditions, responsive to change, verifiable, replicable and which can be measured against a standard or a threshold. Furthermore, an impact should be widely understood by users and relatively easy to measure in both physical and monetary terms. In addition, data to support the usage of the impact should be available.

[131] Some of these agencies include Environment Canada (Canadian Environmental Advisory Council, State of Environment Reporting), National and Provincial Round Table on Environment and Economy, Canadian Council of Ministers of the Environment, Canadian International Institute for Sustainable Development, Agriculture Canada, OECD, United Nations Development Program's Department for Policy Coordination and Sustainable Development (UNDPCSD), Institute for Perspective Technological Studies (EU), Institute of Arable Crops Research (UK), etc.

Table 6.1: Costs & Benefits within an Agricultural Production and Processing System

The impacts of an agricultural production system can be divided into three categories: economic, social and health, and environmental. While environmental and economic indicators remain the most obvious ones, there are many other equally important factors, such as quality of life, human health and well-being at individual and community levels, but these are usually harder to quantify. Some of the main impacts are listed below.

Economic

* Economic costs of production (traditional accounting methods).
  -Annual net returns from farm operations
* Lost value of destroyed produce because of excess pesticide contamination
* Devaluation of farmland prices because of land degradation
* Costs of governmental programs and /or costs of increased conservation/anti-pollution regulations: i.e. subsidies and/or price stabilisation programs, chemical regulation, chemical monitoring (sampling & analysis), implementation and enforcement of such regulations.. etc

Social & Health

Social impacts are defined here as those having an effect on the distribution of income, as well as on the physical well being of individuals and society in general. These include:

* Annual gross farm(ers) income (off and on-farm sources) and impact on living standards
* Levels of rural employment; on and off the farm (full and part time)
* Rates of migration and maintenance of farm population
* Farmer's self satisfaction and satisfaction (fulfilment) from quality of life
* Self sufficiency
* Quality of food and it's consequences on nutrition and health
* Quality of drinking water
* Sickness & death: average number of sick days/farm person/year, type and degree of sickness, frequency of serious accidents
* Livestock health

Environmental

Environmental impacts involve changes in the physical and biological surroundings that affect the welfare, quality of life and income distribution of the population (Sassone, 1978). Impacts include:

* Air quality and climate: ambient concentrations of toxic contaminants
* Surface water quality: concentrations of various farm chemicals & eroded suspended solids (and the effect on fish habitat, recreation opportunities, fishing activities, water storage, conveyance and treatment facilities, navigation etc.)
* Ground water quality: concentrations of various farm chemicals
* Land quality: rate of soil degradation and quality of remaining soil
* Energy use: efficiency, type and quantity
* Total resource use: levels and type (renewable & non-renewable)
* Generation of wastes
* Changes to wildlife and aquatic habitats
* Impacts on flora and fauna: biota, plants, birds, fish, wild animals, livestock, insects especially beneficial arthropods, species health and biological (genetic) diversity
* Deforestation
* Quality of rural landscape and opportunities for leisure

Of the factors listed in Table 6.1, the following environmental and social factors will be considered in this research. These represent some of the main concerns with significant impacts that can be estimated using market-based techniques with more confidence. Including some of the other omitted impacts might have biased the results since no convincing data was available. The studied variables are listed below along with the indicators to be used to measure changes in these key aspects (between parenthesis).

Economic	Environmental	Social & Health
• Annual net revenues from farm operations	• Surface & ground water quality (Levels of various fertilizer and pesticide contaminants) • Agricultural land quality (Levels of various forms of soil degradation) • Off farm impacts (sedimentation)	• Levels of rural employment (Additional on-farm employ-ment opportunities & effect on economy). • Sickness & Death (Average number of sick days/ person/ year from negative exposure to or indirect consumption of agricultural chemicals)

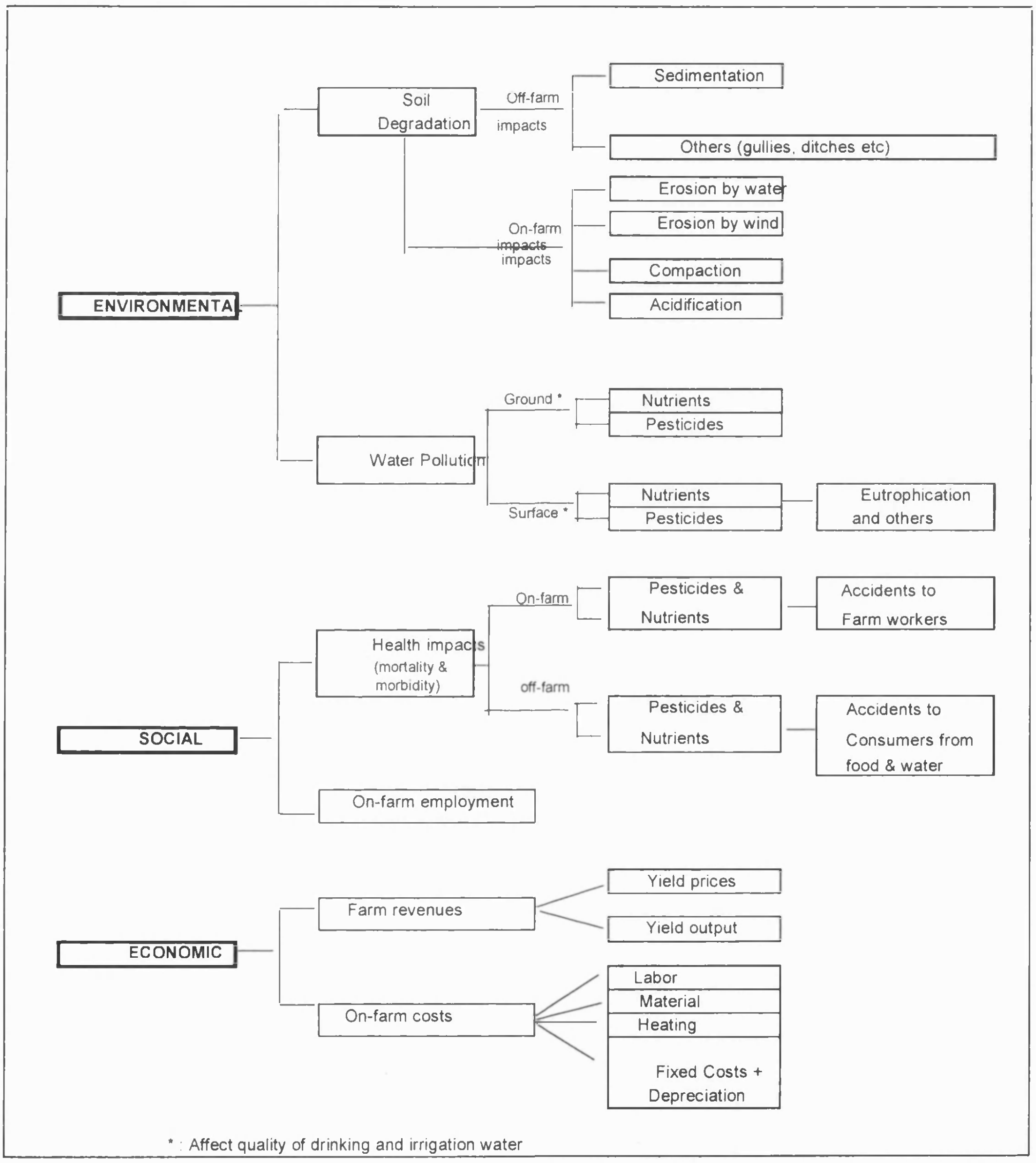
The factors under study are again shown in Figure 6.1 (replicating Figure 4.2). While it is fairly common, in the analysis of projects involving environmental impacts, to omit some variables due to the difficulties in physical quantification or economic valuation, the analysis commonly include a qualitative description of such non-quantifiable effects (World Bank, 1998).

6.4.3. Identifying Data Sources and the Collection Process

The economic costs of production were calculated based on common production practices performed on the typical farm. Financial figures, were determined based on personal interviews with some organic producers, extension agents and consultants in Quebec between 1995 and 2001. Additional information was collected from personal field trips, visits and contacts with horticultural stores, research centres and other organic farms across the province including the Horticultural Research Center and the farm at Macdonald

Campus of McGill University. Reports and production budgets of the "Comité de Réferences Economiques en Agriculture du Quebec

Figure 6.1: The Studied Impacts



Québec[132]" (CREAQ) published by Agriculture Quebec are cited for additional information. Data for social and environmental factors were either collected from

[132] In English, this stands for the Committee for Economic Reference on Agriculture in Quebec.

secondary sources, namely literature reviews or calculated based on appropriate assumptions. These will be discussed in the next section.

6.4.4. Selection of Physical Measurement Techniques

To quantify the physical magnitude of environmental externalities caused by conventional production practices on the typical farm, methodologies will be selected from the techniques discussed in the literature review, as considered relevant and appropriate. The estimates of some impacts will be taken from previous studies in Quebec based on the clarity of their methodology and relevant judgements.

For soil degradation, water erosion will be estimated using the Universal Soil Loss Equation (USLE) based on values of equation parameters determined by Fox and Coote (1986) and Agriculture Canada (1993) soil inventory database for various regions in Quebec. If needed, additional data will be derived from the soil landscape maps derived by Tabi *et al* (1990). Wind erosion will be assumed to be negligible for this part of Quebec as justified by a local literature review.

For compaction, the study will classify the farm potential compaction based on the soil characteristics (texture, organic carbon content, drainage), machinery traffic and weight and crop type based on the qualitative estimates published by Fox and Coote (1986), who classified agricultural lands into five qualitative classes of potential impacts according to the results of experimental studies, literature review and expert opinions.

The extent of acidification will be based on the average nitrogen fertilizer use (fertilizer type and rate) on various crops[133] (specified by the Fertilizer Institute of Canada) and acid rain depositions (Canadian Network for Sampling Precipitation). Secondary estimates will be used.

Off-farm impacts are very hard to measure as they may spread to far places and take different forms. Secondary estimates and figures from literature will be used.

For surface & ground water contamination, the estimates of Environment Canada (1999) which outlined the average amount of pesticides' active ingredients and fertilizers leached per hectare in various drainage basins of the St. Lawrence River will be used. These estimates resulted from chemical laboratory analysis of samples from the drainage basins over an extended period of time. While, it may be difficult to isolate the amount leached from various plantations, it will be assumed to be homogenous across the fields. Therefore, the amount of agricultural chemicals leached from the typical vegetable farm would be equal to the above rate multiplied by the area of the farm. Mathematically, this is expressed as follows:

Kgs of pesticides' active ingredients leached from the typical farm (kg a.i.)	=	Kgs of pesticides' active ingredients leached per hectare in the drainage basin (kg/ha)	*	Area of the typical farm (ha)	**Equation 6.4**

The number of labor hours (and consequently number of workers) required to perform various functions on the organic farm will be estimated based on the time required to perform various production functions. The details are listed in Appendix A. In conventional production, the number of hours will be derived from CREAQ publications.

Estimates of health impacts will de derived from the records of the Anti-Poison Centre of Quebec, which maintains data on incidents related to pesticides, including number of injuries, fatalities, days of sickness, type of treatment administered, age and sex of the patient. It will be assumed that the portion of these incidents that are attributed to the typical farm is proportional to the amount (kilograms of pesticides' active ingredients) used on the farm. The latter is specified in the CREAQ publications, which outlines average production methods. Where data is unavailable, figures will be derived from consultation with agronomic consultants. Mathematically, health impacts can be expressed as follows:

---

[133] Various crops require different nitrogen requirements and have different nitrogen –absorbing efficiency.

$$\text{No. of pesticides-related accidents attributed to the typical farm} = \frac{\text{Kgs of pesticides' active ingredients used on farm}}{\text{Total Kgs of pesticides' active ingredients used in Quebec in 1997}} * \text{The total number of accidents related to agricultural pesticides in Quebec} \qquad \textbf{Equation 6.5}$$

A summary of methodologies used for the physical measurement of impacts is presented in Table 6.2.

6.4.5. Selection of Monetary Evaluation Techniques

Since market prices do not exist for some of the considered environmental and social impacts, indirect valuation techniques are used to estimate shadow prices. The latter are defined as estimates of the economic value of the goods in question, determined from values of similar goods in other markets, consumer surveys or opportunity costs.

The used valuation techniques consist mainly of three methods: The Corrective (Repair) Costs, Defensive (Averting) Expenditures and the Dose-Response methods[134]. The advantage of these methods is that they rely on market prices (of other related goods) and not on hypothetical prices. These will be discussed in more details in the following subsections. It should be noted, however, that in this research, the choice of techniques relied on sensible judgement and reasoning, which was based on expected suitability, nature of the problem and availability of data.

The economic production costs will be derived from standard production budgets produced by Quebec's Ministry of Agriculture. However, since there are no published data for organic vegetables in Quebec (except for some old figures for carrots and cabbage), costs will be calculated based on the production models followed on the farm. These figures are determined using standard budgeting techniques and are supplemented by information collected from interviews with several organic farmers and visits to input suppliers in the

[134] The Corrective Cost approach considers the amount of money paid to offset negative effects and restore previous conditions. Averting expenditures are those made to reduce or avoid a potential problem. The Dose-Response method, in this case, considers the loss of earnings and output of marketable goods such as yield, due to a lower environmental quality change (soil erosion, etc).

Montreal and Laval regions. The production methods as well as gross margins per hectare for various crops are presented in Appendices A and B.

6.4.5.1. Economic Estimation of Environmental Impacts

The economic estimation of environmental impacts will be examined from two perspectives: that of the society as a whole, and that of the individual farmers. For example, land degradation at the farm level consists of direct impacts affecting farm productivity, while the societal impacts consist of off-farm impacts on neighbouring farms and water streams. More details are provided in the following paragraphs.

A. Costs of Land Degradation

The costs of soil erosion will be calculated using both the dose-response and corrective cost methods. Costs, in this case, are based on the value of lost yield (productivity), additional fertilizers and the required cultivation operations (e.g. tillage etc) needed to restore previous farm conditions. The value of lost yield productivity can be mathematically calculated using the following formula:

$$VLc = Pc * Yc * YLc * Lc \qquad \text{Equation 6.6}$$

Where

VL = Value of lost yield ($)
P = Wholesale price of produce ($/kg)
YL = Yield loss in %
Y = Average yield (kg/ha)
L = Affected crop area (ha)
c (subscript) = Vegetable crop

This method is used since it is straightforward and can easily be understood by farmers. Experienced farmers can usually approximate data on yield change, as a result of soil degradation. However, sometimes there may be some difficulties in isolating the impacts of erosion from other factors affecting yield (weather, pests etc). Economists have used modelling techniques such as regression analysis for this purpose (Lutz *et al.*, 1994).

Since data on the net effects of soil erosion (current & future) on productivity in Quebec are sketchy, an estimate will be developed from discussions with various producers and soil experts. The same method will be used to estimate a value for additional fertilisers and cultivation operations needed to offset erosion damage. The results and assumptions used are discussed in detail in Appendix A.

To estimate an economic value for compaction, the dose-response method, which considers the value of lost yield, will be used. Yield change as a result of compaction can usually be determined through field experimentation and from technical literature for similar field conditions. Economists can also determine yield change by regression modelling.

Mathematically, the value of yield change as a result of compaction can be calculated using the following formula:

$$VLc = Pc * Yc * YLc * Lc \quad \textbf{Equation 6.7}$$

Where

VL = Value of lost yield
P = Wholesale price of produce ($/ha)
Y = Yield (kg/ha)
YL = Yield loss %
L = Affected crop area (ha)
c (subscript) = vegetable crop

Other methods, such as the Repair Costs method, which considers the costs of cultural practices followed to reduce compaction, could have been used. In such case, both the initial and final conditions of the soil must be specified for various years, along with the techniques used to offset compaction (e.g. ploughing using different equipment, plant rotation etc.)[135] . However, the first method was used since it was more direct and involved fewer assumptions. Additionally, the cost of sub-soiling, which is done once every ten years, will be added to the above costs.

---

135 Average costs to repair compaction through the installation of tile drainage and sub-soiling are available. However, the practice of installing drains is usually avoided because it is an expensive solution, while sub-soiling has a negative impact on soil productivity as it turns over the nutrient-rich topsoil.

Acidity costs will be accounted for by considering the value of corrective costs, i.e. in this case, the value of lime added to offset acidity. This method is chosen since acidity can be almost completely corrected for by the addition of lime, and since this practice is widely used in Quebec. The dose-response method, which depends on estimating yield change as a result of acidity, could have also been used, but the estimates may require additional assumptions and direct data since yield loss as a result of acidity is a function of factors such as the soil buffering capacity, physical characteristics, and drainage ability. In this case, soils with similar pH levels may produce different effects on yield (Mehuys, 1984). Hence the cost of lime remains a more direct method. The costs of lime equivalent on moderately sensitive and sensitive soils[136] can be calculated using the following formula:

$$VL = P * L * (AF + AA)/1000$$ **Equation 6.8**

Where

VL= value of lime equivalent ($).
P = Price of lime ($/tonne).
L = Affected hectares of land that are sensitive and moderately sensitive.
AF= Average dosage of lime to neutralize annual fertilizer induced acidification (kg/ha).
AA= Average dosage of lime to neutralize annual acid precipitation (kg/ha).

As for the off-farm costs of land degradation, which are mainly composed of the negative impacts caused by sedimentation in neighboring fields and water bodies, impacts on fisheries, water-based recreation and navigation, the corrective cost method is used. This method considers the repair costs to gullies, structures and water bodies. The dose-response method was not used because it was difficult to isolate the (off-site) impacts resulting from the typical farm from that of other neighboring farms. Additionally, it was difficult to isolate the resulting impacts (on yield change in neighboring farms) from that of on-farm erosion. Preventive costs could also be used when sufficient information is available. However, since sedimentation repair costs are not available in Quebec, these will be

[136] Soil sensitivity to acidification is measured in terms of the potential change in soil bases present in the surface soils (exchangeable bases). This potential is less than 6 meq/100 gm for sensitive soils and from 6 to 15 meq/100 gm for moderately sensitive soils.

extrapolated from either U.S. or other Canadian studies using the Benefit-Transfer method. The formula for this method can be stated as follows:

$$Ij = (Yi/Yj)^{E} * Ii \qquad \text{Equation 6.9}$$

Where

Ij = Impact value for country j
Yj = Income in country j
Yi= Income in country i.
E = Income elasticity of demand for environmental benefits
Ii = Impact value for country i

A summary of the physical and monetary evaluation techniques for land degradation is presented in Table 6.2.

Table 6.2: Summary of the Physical and Monetary Evaluation Techniques for Land Degradation

Impact	Physical Measurement & Assumptions	Monetary Measurement & Assumptions
Erosion by water	**Universal Soil Loss Equation, parameters from Fox & Coote (1986) & Tabi *et al.* (1993)**	**Dose response & corrective costs: Values of lost yield & costs of additional fertilizers and cultivation practices.**
Compaction	**Qualitative classification based on crops, soil characteristics and cultural practices. Classification based on expert opinions and experimental studies (Fox & Coote, 86 and Mehuys, 84).**	**Dose response & corrective costs: Values of lost yield productivity & costs of sub-soiling**
Acidification	**-Change in acidity levels due to nitrogen & sulfur fertilizers**	**Corrective costs: costs of lime equivalent to correct pH.**
Off-farm impacts	**Measurement of sediment buildup based on data collected from monitoring stations.**	**Benefits transfer method considering corrective/repair costs to gullies & structures & sediments removal from water bodies.**

B. Costs of Water Pollution

The method used to estimate the costs of water pollution depends usually on the main source of (consumption) water in the areas with potential contamination (i.e. rivers, wells, purchased tanks etc.). For example, for areas that depend on a water treatment plant, the

Corrective Costs Method[137] is usually used. This consists of the total municipal water treatment costs to provide the volume of water to satisfy the needs of the population in the affected region. Domestic water needs can be estimated based on the Canadian average water consumption per capita[138]. In rural areas, additional water may be used for livestock and other domestic needs. Farmers in Quebec are not allowed to use municipally treated water for irrigation, but have to rely on wells and water collected in ponds.

If the source of water was from a private well, then the Averting or Defensive Expenditure method could be used. This consists of expenditures made to avoid potential health problems. This may include domestic water filtration units or the purchase of an equivalent volume of clean water from an external source. The price of filtration units of various capacities can easily be determined from local suppliers.

In this research, the social costs of water contamination generated by conventional production on the typical farm are equivalent to the portion of the water treatment costs in the Monteregie region attributed to the farm based on the proportional volume of chemicals active ingredients leached from the farm area (pollution). In other words, this is equivalent to the ratio of the pesticides' chemical ingredients leached by the farm over the total pesticides' active ingredients leached from the total area of Monteregie, multiplied by the overall bill of municipal water treatment in the Monteregie region based on the average yearly volume of water consumed by a Canadian resident and treatment costs of municipal water. This can be mathematically stated as:

$$\begin{array}{l}\text{Costs of water}\\ \text{contamination}\\ \text{attributed to the}\\ \text{typical}\\ \text{farm (\$)}\end{array} = \frac{\begin{array}{c}\text{Kgs of pesticides' active}\\ \text{ingredients leached from the}\\ \text{typical farm (kg a.i.) (Eq. 6.4)}\end{array}}{\begin{array}{c}\text{Kgs of pesticides' active}\\ \text{ingredients leached from the}\\ \text{Monteregie region}\end{array}} * \begin{array}{l}\text{Total municipal water}\\ \text{treatment and delivery}\\ \text{costs in the Monteregie}\\ \text{Region}\end{array} \qquad \textbf{Equation 6.10}$$

Where

[137] It should be noted that only the direct usage value of water is considered. Therefore, for drinking water, corrective costs apply to the volume of water required for human consumption. This, off course, does not reflect the river cleanup costs. In a way, these costs can be considered as averting expenditures to avoid health problems.

[138] Estimated at 340 liters per day (Environment Canada, 1994).

Total municipal water Treatment costs in the Monteregie region ($/year)	=	Average annual water consumption volume per capita in Canada (cubic meters/capita/year)	*	Population of the Monteregie region (capita)	*	Annual costs of municipal water ($/cu. m)	**Eq. 6.11**

Two main assumptions are made here: 1) that the whole region relies on municipally treated water extracted from both surface sources and wells, which is a fair assumption since only residents of remote areas depend on other water sources; and 2) that the water contamination levels have exceeded the allowable human-safe threshold. The review of literature indicated that this was the case in some regions of the Montregie. Additionally, the above costs include the treatment costs of water consumed on the farm.

It may be argued that by using this method, the costs of water pollution from agricultural contaminants may be overestimated, since treatment plants have been designed to treat a wide variety of contaminants and not only agricultural contaminants, and in many cases, the other contaminants are a larger source of concern. However, the following arguments could defend the use of the Corrective Costs method: 1) it is difficult to isolate the water treatment costs (and sometimes the technical process) of pesticides and other agricultural chemicals from other contaminants; 2) even if it was technically possible to do so, using such figures (i.e. x$/kg of contaminant) generated from a large scale of operations for a small volume of contaminants is inaccurate since the costs per unit (of contaminant) will change when the plant is operated on a small scale (many overhead/fixed costs are incurred regardless of the volume)[139]; 3) treatment for specific agricultural pollutants may be as costly as the general treatment process, and full treatment has to be done, for public safety, even when only a single agricultural contaminant exists. Additionally, there may be some difficulties in determining the exact estimate of the damage caused by the typical farm due to the many variables involved.

It is also believed that water treatment costs (per cubic meter) are still much lower than costs generated by other techniques such as defensive expenditures that consist of costs of providing alternative sources of consumption or drinking water. Furthermore, water

[139] The Average cost curve is U-shaped. This means, higher costs at low and high volumes.

treatment costs are believed to be lower than the expected health costs from the consumption or usage of untreated water.

Other techniques such as Contingent Valuation (CV) and Revealed Preferences RP) could be used, but these are more costly and time consuming, and since market-based techniques are often more practical to use.

It should be noted that this research does not consider the non-use values of clean water and the costs of lost recreation and damages to fish since it is difficult to relate these aspects of environmental damage to the activities of the typical farm. In addition, part of the costs of sedimentation is included under the off-site costs of land degradation. A summary of the physical and monetary evaluation techniques for water pollution is presented in Table 6.3.

Table 6.3: Summary of the Physical and Monetary Evaluation Techniques for Water Pollution

Impact	Physical Measurement & Assumptions	Monetary Measurement & Assumptions
Surface & ground water	Chemical analysis of levels of agricultural chemicals in drainage basins	Municipal water treatment costs attributed to the typical farm

6.4.5.2. Economic Estimation of Social and Health Impacts

6.4.5.2.1. On-Farm Employment

Since organic production is more labour intensive, the conversion to organic production practices will result in the creation of (additional) on-farm employment opportunities (full time and temporary) with considerable benefits to the economy[140]. Part of these benefits is directly related to the newly employed workers, and indirectly through the multiplier effect of these jobs on the economy, in general. The analysis will be mainly based on the

[140] Organic farming may create additional off-farm related jobs such as in packaging, marketing, processing and sales (specialized outlets) of organic produce and in the manufacturing of organic compounds etc. Some of these may be new jobs or the functions could be done by those already dealing with conventional products. However, off-farm jobs will not be included as they are hard to estimate.

Keynesian model for GDP estimation[141]. This item is sensitive to the macro-model assumed; this may be contentious and should be regarded as no more than illustrative of a particular approach. The approach selected will give top-end estimates of possible effects.

It is sometimes argued that employment impacts should not be considered in CBA, since any expenditure will generate these. However, the researcher believes that it is appropriate to consider them in this case, since the research is explicitly considering the replacement of one technique of production by another and the techniques differ in labor intensity. The problematic issue is whether to include second round effects. It could be argued that it is appropriate to do so since these would not be observed without the original switch of techniques. It should be recognized that this is a debatable issue.

Assuming that the newly employed workers were previously receiving government welfare payments, the generated benefits can be divided into four categories or effects: A) Consumption effects: benefits to the overall economy due to the increased contribution to GDP[142] because of increased net income of the newly employed. A higher net income means higher rates of consumption and savings; B) Tax effects: governmental revenues will increase from additional income taxes collected from the newly employed workers. It is assumed that these revenues will be re-invested in the economy in the future[143]; C) Governmental expenditures/transfer payments effects: governmental expenditures on welfare payments are expected to decrease due to the decrease in the number of unemployed. It is assumed that this may eventually have a positive contribution to the economy not only as reduced expenditures, but also as the government might spend this amount on other useful purposes[143]; and D) the effects on imports which are usually expected to rise with increased income. Increased imports are expected to reduce growth in GDP. In summary, the direct benefits to the economy from creating jobs can be expressed using the following formula:

[141] The Keynesian model for estimating GDP based on aggregate expenditures states that GDP = consumer spending (C) + investment spending (I) + government purchases (G) + net exports (exports (X) – imports (M)).

[142] Due to increased aggregate demand or aggregate expenditures.

Direct Benefits to the economy = net wages + reduced transfer payments + increased governmental taxes + imports effects **Eq. 6.12**

$$= L*W + L*WP + L*W*t - \Delta Yd*mpm$$ **Eq. 6.13**

Where

L = number of new jobs created
W = wage rate ($/year)
WP = welfare payment ($/person/year)
ΔYd = change in disposable income
t = tax rate (%)
mpm= marginal propensity to import, equal to change of imports/ change in disposable income.

Indirect effects result from the multiplier effect of the above factors as follows:

$$Total\Delta GDP = \Delta GDP_c + \Delta GDP_t + \Delta GDP_g$$

Eq. 6.14

Where

ΔGDP = total change in GDP (in either organic or conventional production).
$\Delta GDPc$ = change in GDP as a result of increased workers consumption
$\Delta GDPt$ = change in GDP as a result of increased tax revenues
$\Delta GDPg$ = change in GDP as a result of decreased transfer payments

With

$$\Delta GDP_c = \Delta C * SM_m$$ Equation 6.15

$$\Delta GDP_t = \Delta T * TM_m$$ Equation 6.16

$$\Delta GDPg = \Delta G * SM_m$$ Equation 6.17

Where

[143] Potential re-spending is not calculated in the indirect benefits as it depends on future government behavior and fiscal conditions.

ΔC = Change in (net amount of money available for) consumption as a result of increased income, which is equal to Δ Income * mpc. Note: Δ Income = Δ labor hours * wages.

SMm = Spending multiplier adjusted for taxes and imports = 1/{1-mpc(1-t)+mpm} with mpc = marginal propensity to consume, derived from the average consumption function of a person resident in Quebec, and mpm = marginal propensity to import (from other provinces and from other countries)..

ΔT = Change in tax revenues due to increased income of the newly employed

TMm = Tax multiplier adjusted for taxes and imports = -mpc (1-t)/{1-mpc(1-t)+mpm}, with mpc = marginal propensity to consume, derived from the consumption function of an average Quebec resident, and mpm = marginal propensity to import.

ΔG = Change in governmental expenditures on welfare payments

t = tax rate

The above variables will be derived from relevant governmental publications.

6.4.5.2.2. <u>Health Costs</u>

Health costs will be limited to the acute impacts on Quebec's population as a result of consuming chemically polluted food and water as well as other on and off-farm accidents related to agricultural chemicals (handling, inhaling etc.)[144]. Data are collected from Quebec's Anti-Poison Centre. Data on chronic accidents will not be used since they are sketchy, and since it is very difficult to isolate the effects of agricultural chemicals from other causes.

Health costs consist of direct and indirect costs[145]. Indirect costs will be valued using the Human Capital Approach (HC), and is equal to the discounted projected future gross earnings lost due to premature death and absenteeism due to injury. If the injured is a child, it will be assumed that one of his parents will have to be absent from work. In the case of fatalities, values of these earnings will be based on the average expected life span of the Quebec or /Canadian population, age and sex of individual, and the average returns per year

[144] Accidents related to agricultural machinery are assumed to be, more or less, of equivalent risk in both organic and conventional agriculture, and therefore, will not be considered.

[145] Direct costs include costs of treatment (medication and hospitalisation) while indirect costs include earnings lost due to absenteeism and death.

according to the affected person's profession. If the profession is not known, the average Canadian income is used. In the case of injury, lost earnings will depend on the period of absenteeism using the same salary scale. In addition, a value for lost leisure time to sick persons, valued at one-third of the post tax wage, will be added.

Direct costs will include medication and hospitalisation costs paid by the injured person based on the average days spent in hospital and type of treatment. These costs will be obtained form hospitals in the Montreal region. For simplicity, it will be assumed that these injuries will not cause any permanent damage to the injured person so as to affect his future productivity at work.

The HC method is chosen because it's a widely used technique. Furthermore, it relies on market data unlike the Contingent Valuation Technique (CV), which relies on hypothetical estimates. This latter was not used here to avoid the many biases inherent in the method.

Health costs can be mathematically stated as follows:

$$\mathbf{THC = TMHC + TLPC + TVLT} \qquad \text{Equation 6.18}$$

Where

THC = Total health costs ($)
TMHC = Total medication and hospitalization costs ($)
TLPC = Total lost productivity costs ($)
TVLT = Total value of lost leisure time ($)

The portion of the total health costs that can be attributed to the typical farm is proportional to the amount of pesticides' active ingredients used on the farm, as outlined in the CREAQ publication, over to the total amount of pesticides' active ingredients applied to the province's agricultural land. The latter, estimated at 2,732,751 kg a.i. in 1997, is derived from a report by Quebec's Ministry of Environment (2000). The health costs can be mathematically stated as:

$$\text{Health costs attributed to the typical farm (\$)} = \frac{\text{Kgs of pesticides' active ingredients applied to the typical farm (kg a.i.)}}{\text{Kgs of pesticides' active applied on agricultural land in the province (kg a.i)}} * \text{Total agric. pesticides -related health costs in the province (Eq. 6.18)} \qquad \textbf{Eq. 6.19}$$

A summary of the physical and monetary evaluation techniques for social and health costs is presented in Table 6.4.

Table 6.4: Summary of the Physical and Monetary Evaluation Techniques for Social & Health Costs

Impact	Physical Measurement & Assumptions	Monetary Measurement & Assumptions
1- Health: **A- Accidents from agricultural chemicals (on and off-farm).** **B- Consumption of food and water contaminated with chemical residues**	**Statistics on the number of related accidents from Quebec's anti-poison center**	**Costs of illness: include costs of medication, hospitalization plus lost wages (in case of absenteeism) and lost expected gross future earnings (in case of death) plus value of lsot leisure time attributed to typical farm**
2- Additional on-farm employment opportunities	**Additional number of hours (and laborers) needed in organic production on the typical farm**	**Change in aggregate expenditures and effect on GDP from increased disposable net income to the laborers plus the effect of tax savings on the public from reduced welfare payments (to previously unemployed laborers)**

6.4.5.3. Estimation of Production Costs

The crop production costs in this study include (variable and fixed) operating and initial costs. Examples of the former include material, labour and (machinery) fuel, while initial costs are comprised of the costs of machinery, land and farm structures. All these costs are normalised for the reference year 1997. Farm income is a function of yield and crop prices.

For the vegetable crops under study, production costs are mainly derived from the CREAQ publications of Quebec's Ministry of Agriculture, which shows detailed production budgets. These publications accounted for the conventional production of most vegetables, but only for two organically grown crops: carrots and cabbage, but these two date back to 1990. Therefore, it was necessary to estimate directly new production budgets for organic vegetables. Financial figures are calculated based on common practices outlined by several organic producers and extension agents. The data was collected through personal interviews and farm visits between years 1995 and 2001. A detailed description of the approach used along with the assumptions about yield, prices and production practices is summarised in Appendices A and B.

6.5. The Discount Rate

In this research, a discount rate that is 2% below the (yearly average) rate on long-term Canadian government bonds[146], adjusted for inflation, is used for the extended analysis. This rate, chosen arbitrarily as a starting point, is selected to be lower than the regular rate used in public policy making to better reflect sustainability criteria and a socially sensitive opportunity cost of capital, since the analysis is performed from a societal perspective. For the conventional analysis, the rate used is equivalent to a commercial rate, which is assumed to be the government bonds rate plus a premium of 2%, which reflects risk and a profit premium.

The adjustment for inflation is done using the following formula[147]:

$$\textbf{Real discount rate} = \{(1+\textbf{nominal interest rate})/(1+\textbf{inflation})\}-1 \qquad \text{Equation 6.20}$$
$$\Rightarrow \textbf{Real discount rate} = (\textbf{nominal interest rate} - \textbf{inflation})/(1+\textbf{inflation})$$

The average inflation rate for the past five years is used. It should be noted that this real discount rate is to be considered as a starting point. A sensitivity analysis will examine how results vary under different rates. Furthermore, the results are compared to the rate at which the Net Present Value changes in sign from positive to negative.

[146] 25 years or the closest possible (to match the time frame of analysis).
[147] The equation accounts for the Fisher effect, where the nominal rate includes both the real rate, inflation rate and a cross product of the two rates, i.e. Knominal = Kreal+Inf.+Kreal*Inf. Many references ignore the cross product.

Risk can usually be accounted for in either one of the following two ways: 1) adjusting the discount rate, or 2) finding certainty equivalents for the expected cash flows. The latter is difficult since there is not enough information to assign probabilities to various outlays.

Adjusting the discount rate to account for risk can also be done through the use of the Capital Asset Pricing Model (CAPM). In this case, the discount rate is equal to the risk-free rate plus a risk premium, as follows:

$$\begin{aligned} \mathbf{K_s} &= \mathbf{K_{rf}} + \textbf{risk premium} \\ &= \mathbf{K_{rf}} + (\mathbf{K_m} - \mathbf{K_{rf}}) * \mathbf{b_i} \end{aligned} \qquad \textbf{Equation 6.21}$$

Where
K_s = Risk-adjusted discount rate
K_{rf} = Risk-free discount rate
K_m = Required rate of return on market
bi = Measure of risk for this project (or certain stock, in general)

The risk premium can usually be estimated on the basis of *ex post*, or historical returns, or 2) *ex ante*, or forward returns. A common source in North America is Ibbston Associates (Brigham and Gapenski, 1996) have annually published a comprehensive study on risk premiums using an extensive set of data from 1926. However, their results apply more to financial investments such as T-bills, T-bonds, stocks and corporate bonds, but not for general or other types of projects or investments. The latter can be extracted from publications of various corporations within a certain industry, e.g. the car industry. The beta (bi) is usually measured by running a linear regression between past returns on the stock and past returns on some market index. Alternatively subjective estimates can be used for new projects.

Again, due to difficulties in estimating the required variables, no risk premium will be added to the used rate. Uncertainties in either the discount rates or in measuring various costs and benefits will be examined in the sensitivity analysis.

6.6. The Weighting System

The purpose of this system in this research is to reflect the relative importance (and indirectly the seriousness) of the economic, social, and environmental components under study to the region or Quebec's population. This will allow for the combination of all these impacts to achieve an overall measure of the net benefits of each production system.

Two approaches can be used: 1) public surveys, whereby a sample of population is asked to rank or weigh the issue(s) that concern them most regarding conventional agriculture in general, or a current situation/problem in particular[148]; and 2) expert opinions gathered with appropriate techniques.

One of these techniques is the Delphi technique. It involves the participation of a group of experts who are asked independently, to weigh/rank the importance of different impacts caused by conventional practices. In a closed meeting, panel members are asked to submit their estimates in writing to a moderator. In this way, indirect communication between the panel members is maintained. This is important to avoid the influence of personality in the evaluation process. Results are statistically analysed and reported back to the panel in the same session. The experts with the extreme figures are asked to submit a written explanation for their figures. This information is then fed back to the participants who are asked to revise their estimates. Through successive rounds of feedback, a consensus may be reached toward a group mean.

A critical issue in using these techniques is the appropriate choice of panel members or the sample for the public survey. An ideal representative group should contain people from different backgrounds (urban/ rural, professions etc.) who are well aware of the problem. The technique can be undertaken in a short period of time and is relatively not expensive.

For this study, the basic analysis will assume that weights of various impacts are equal, i.e. all impacts are equally important to the society in Quebec. This is chosen to avoid making invalid assumptions since the derivation of weights involves at least two factors, ecological and political, both of which can not be completely defined for this study. The first factor helps to determine how far are the current environmental conditions from the system's carrying capacity or sustainable resource use level, while the political factors help to reflect

[148] The use of existing (relevant) surveys can also serve the purpose, i.e. works of Weymes (1990) and Environmental Monitor (1993).

the policy makers' pursuit toward a predefined social welfare function, which may also change over time[149]. However this assumption is a starting point and the results ensuing from different variations of weights will be looked into using a sensitivity analysis. It should be noted that choosing an objective manner to derive weights for various components has been a contentious issue (Lampkin, 1998 and Stolze *et al.*, 2000).

6.7. Sensitivity Analysis

Since the human understanding of the complex environmental impacts is somewhat limited in general, and due to the several assumptions used in this research, calculation methods and estimates of future costs and benefits, the results of the analysis may have some uncertainties[150], which may affect the confidence in the results. Therefore, a sensitivity analysis will be carried out to determine how sensitive the values of NPV are under a range of possible variations in the values of the studied variables. These variations can be the result of incorrect assumptions made at present or possible changes in the future values of some variables, especially environmental ones, which are likely to change in physical magnitude and consequently in monetary value.

Sensitivity analysis will also increase the level of information, reveal a better picture of the degree of risk involved and will help the decision-maker to reach a better overall judgement. It will also help to focus attention on the variables that need to be better understood, evaluated, monitored or managed in the future[151]. Sensitivity analysis will also help to confirm the broader conclusions of the analysis.

The suggested sensitivity analysis will examine how sensitive results are to changes in the discount rate (from -5 to +5% of the used rate), time horizon (from 10 to 25 years at 5 years interval), weights of different groups of components (up to 50%), and various expected values of some variables[152] (from -50% to +50% of the estimated figure). The sensitivity

---

[149] In this case weights will change over time.

[150] As mentioned earlier, it is difficult to determine probabilities of risk involved, and therefore, certainty equivalent values could not be used.

[151] It will also help to show where preventive measures are needed

[152] The main variables include change of yield, environmental and social impacts.

analysis treats every change in a variable in isolation of other changes, i.e. assumes that all other variables remain constant. This will help to show which variable change is relatively more important than the other, and therefore shows where any policy change would be more effective.

In reality, it is possible for more than one variable to change at the same time. For this reason, the analysis will evaluate four additional scenarios, where the three key variables mentioned above are varied at the same time. The four scenarios are: very pessimistic, pessimistic, optimistic and very optimistic with the three key variables changed simultaneously at –40%, -20%, +20% and +40% of the measured values, respectively. This is to insure that results are solid enough. For example, an optimistic measurement is when benefits are 20% higher and costs are 20% lower.

The analysis, however, will not consider what happens if two or more variables change simultaneously at different rates. These are specific cases that should be evaluated separately, on a case by case basis, based on experts' forecasts and specific demand. Risk analysis can further be studied with the assigning of subjective probabilities for various scenarios and the calculation of relevant standard deviations and other statistical measures. (This is beyond the scope of this project).

6.8. The Comparison

Using conventional and extended CBA techniques, the present value of the overall stream of expected net returns to organic and conventional vegetable production systems will be compared. The scenarios to be compared are listed in Figure 6.2. A fifth comparison will also be done between the extreme cases, i.e. cases 1 and 4.

Figure 6.2: The Comparison Cases

	Conventional Production (C)	Organic Production (O)
Conventional CBA (CC)	Case 1	Case 2
Extended CBA (EC)	Case 3	Case 4

Cases 1 and 2 consider the private costs and benefits to the farmers using standard (commercial-like) procedures with no consideration of externalities, while in cases 3 and 4, the analysis is done from a societal perspective using environmentally sensitive criteria and the other suggested extensions. The comparison of cases will look at the difference between the net benefits of each case according to the following formula:

$$\sum_{t=0}^{T} \frac{\left(\Pi_t^O - \Pi_t^C\right)}{(1+r)^t}$$

Equation 6.22

Where

Π_t^O = Net farm returns of case O at time t[153].

Π_t^C = Net farm returns of case C at time t.

With

$$\Pi_t^o = \left(\sum_i^n Y_i\left(P_{it}^o - C_{it}^o\right)\right) - EDC_t^o + EB_t^o - HC_t^o - I_t^o$$

Equation 6.23

And

$$\Pi_t^c = \left(\sum_i^n Y_i\left(P_{it}^c - C_{it}^c\right)\right) - EDC_t^c + EB_t^c - HC_t^c - I_t^c$$

Where

Yi = Units of yield for a certain crop i. at time t
Pit = Price of yield for a certain crop i. at time t ($/Unit of yield)
Cit = Operating production costs for a certain crop i. at time t
EDCt = Costs of environmental degradation at time t (if applicable)
EBt = Employment benefits at time t
HCt = Human health costs at time t (if applicable)
It = Initial investment costs
o = Organic case
c = Conventional case

153 For this value to become a cash flow, it has to be adjusted for tax, depreciation, salvage value effect and changes in net working capital.

If the NPV of incremental returns to the farmer and the society from conversion to sustainable practices is positive, then the organic system of production will be an improved production option worth of consideration.

Depreciation will also be accounted for in the above equation using the Straight- Line method.

CHAPTER 7
RESEARCH RESULTS

7.1. Introduction

In this chapter, the results obtained from the analysis are presented and discussed under three main headings: 1) farm budgets including social and environmental costs; 2) cash flow and CBA results; and 3) the sensitivity analysis.

7.2. Farm Budgets, Environmental and Social Impacts

7.2.1. Economic Budgets

Production budgets for conventionally produced crops were derived from CREAQ budgets published by the Quebec Ministry of Agriculture (QMA). For organic crops, since QMA published only budgets for carrots and cabbage in 1990, costs of production had to be calculated directly based on the production practices performed on the typical farm. Production details and detailed budget calculations are discussed in Appendices A and B. All the figures were transformed into 1997 dollar values using the Farm Input Price Index (FIPI) for the inputs and the Farm Output Price Index (FOPI) for the output (produce). The crop prices consisted of the average wholesale prices as derived from major organic wholesalers in the Province. A summary of production budgets for each plot given the rotation plan is listed in Tables 7.1A, 7.1B and 7.1C.

Table 7.1A: A Summary of Production Budgets for Conventional Crops (1997 C$ per plot)

	Plot 1 Cabbage	Plot 2 Carrots	Plot 3 Beans	Plot 4 Lettuce	Total Farm ($)
Total revenues	36,123.51	44,619.12	9,495.50	90,240	**180,478.13**
Total operating costs	16,937.28	37,231.66	11,286.60	28,460.89	**93,916.42**
Net returns	19,186.23	7,387.46	-1,791.10	61,779.11	**86,561.70**

Source: CREAQ Publications, Quebec Ministry of Agriculture.

Table 7.1B: A Summary of Production Budgets for Organic Crops (1997 C$ per plot)

	Plot 1 Cabbage	Plot 2 Carrots	Plot 3 Beans	Plot 4 Lettuce	Plot 5 Green Manure	Total Farm ($)
Total revenues	90,816	55,808	22,821	110,592	0	**280,036.58**
Total operating costs	33,360.57	44,287.05	16,717.85	30,248.7	7,159.80	**131,773.98**
Net returns	57,455.43	11,520.95	6,103	80,343.3	-7,159.80	**148,262.60**

Table 7.1C: A Summary of Production Budgets for Organic Crops during Transition Phase (1997 C$ per plot)

	Plot 1 Cabbage	Plot 2 Carrots	Plot 3 Beans	Plot 4 Lettuce	Plot 5 Green Manure	Total Farm ($)
Total revenues	24,425	24,486	6,457	72,192	0	**127,559.98**
Total operating costs	30,396.92	43,250.01	16,260.11	28,854.8	7,159.80	**125,921.63**
Net returns	-5,971.64	-18,764.25	-9,803	43,337.2	-7,159.80	**1,638.35**

The tables above showed that organic production (after transition) had higher operating costs (40.1%) and revenues (55.16%) than conventional production. In terms of gross revenues, it generated about 71.3% higher revenues than conventional production on a whole farm basis annually.

Initial investment for both production systems were calculated based on fixed farm assets including the set of machinery/equipment used on the farm (details in Appendices A and B). Depreciation of capital expenditures was calculated using a Straight-Line Method assuming an annual depreciation rate of 5% for buildings and 10% for farm equipment. Final market salvage value was assumed to be equivalent to the book value. The value of land is assumed to appreciate at a rate of 2% per year. A summary of these costs is listed in Table 7.2.

Table 7.2: Summary of Capital Investment and Depreciation Costs (1997 C$)

	Conventional Production	Organic Production
Capital investments	**400,450**	**404,100**
Annual depreciation costs [1]	**27,486.9**	**27,851.9**

Notes: Does not include the appreciation of land.

7.2.2. Environmental Impacts

7.2.2.1. Soil Degradation

Soil degradation consisted of four impacts: soil erosion by water, compaction, acidification and off-farm impacts. Water erosion was estimated using the Universal Soil Loss Equation (USLE). The values of the equation parameters were determined from Fox and Coote (1986) and Agriculture Canada (1993) soil inventory database. Accordingly, erosion on the sample farm was in the low erosion potential class (6 to 11 tons/ha/year)[154]. In monetary values, impacts of erosion were estimated using the dose-response and corrective cost methods, which considered the effects on farm productivity and costs of additional cultural practices and fertilizers to offset the impacts of erosion. The impact of erosion on yield was determined based on discussions with various Quebec producers between 1995 and 2001. The assumptions made along with the time path of yield are discussed in Appendix A.

For this study, an annual yield loss of 5% is assumed to occur in the sixth year and gradually increases by 2% until the end of the tenth year when soil rich in organic matter (compost @ 40 tons/hectare) is added to help improve soil conditions. Fox and Coote (1986) did not report a yield loss for such an erosion rate[155]. These estimates are lower than the figures reported by Agriculture Canada (1985). Yield change due to soil erosion is illustrated graphically in Figure A-1 (Appendix A). The above assumption applies also to crops that are sold by units (e.g. lettuce). The latter yield is assumed to be of lower quality (size) and, therefore, would receive a lower price. Since these figures are uncertain, a sensitivity analysis will account for various estimates of productivity change. It will also be assumed that this loss of yield will not affect prices due to the limited effect of farm produce on the aggregate supply.

Additionally, the costs of supplemental fertilizers and corrective farm cultivation operations (to replace nutrients lost through erosion and to correct for on-farm erosion damage[156]) are assumed to be equivalent to 3% of annual variable production costs, applicable from the sixth to the tenth year[157]. The main assumption here is that the original levels of nutrients originally applied to the land, prior to the occurrence of erosion, were not in excess, and that their loss will affect productivity.

---

[154] The values here are predicted and not existing soil loss rates. These will be used given the paucity of real data.

[155] Fox and Coote (1986) reported that yield would decrease by 15% and 40% on moderately (10 to 25 tons/ha/year) and severely eroded soils (> 25 tons/ha/year) in the St. Lawrence region of Quebec, respectively. Their conclusions were based on meetings with groups of experts and from extensive farmer surveys.

[156] Repair of physical damage includes filling the gullies and repair of drainage outlets.

[157] Fox and Coote (1986) used a figure of 5%.

For organic production, erosion is assumed to be smaller than the one witnessed in conventional production due to the continuous planting of cover crops and minimal soil disturbance. However, yield decrease is assumed to be insignificant due to the systematic soil building with the application of compost and green manure. The total costs of erosion under both production systems are listed in Tables 7.3A and 7.3B

Soil compaction was estimated qualitatively based on the soil physical characteristics (texture, soil organic content and drainage) of the farm, frequency and weight of tillage and other machinery operations. The current farm practices on the typical farm would classify compaction as moderate based on Fox and Coote (1985) classification. The authors relied on expert opinions, literature review and experimental studies. In monetary terms, the costs of compaction were estimated using the dose-response method, which mainly considered the effects on farm productivity, i.e. the value of lost yield. An annual estimate of 10% of the value of yield is used starting from the second year. This value is determined from discussions with farm operators in the region, and is considered to be a conservative estimate for compaction. It was also assumed that the annual land preparation (for planting) practices would slightly improve soil structure and neutralize the effects of compaction caused by production practices during the previous year. Additionally, sub-soiling is done once every five years to help loosen the deep soil layers.

This figure is not high since compaction has been recognized as the most serious problem in the region (Mehuys, 1984) causing an average yield loss of 15% on all crops in the province. In comparison, Fox and Coote (1986) estimated the effect on vegetable yield to be 10%, 30% and 50% on highly compacted sandy, loamy and clayey soils, respectively.

Under organic production, the typical farm is assumed to have a good soil structure due to proper organic matter management, planting of green manure, rotation, less usage of machinery and minimum soil tillage. Still some compaction is expected to occur due to some machinery usage but it is assumed to have a minimal effect on yield. This assumption was mainly based on discussions with agricultural experts. Deep sub-soiling is practiced once every five years. The total costs of compaction under both production systems are listed in Tables 7.3A and 7.3B.

Soil acidification has a potentially problematic effect on conventional production since (nitrogen) chemical fertilizers are used. Based on personal discussions with agricultural experts in Quebec, it was concluded that acidity had mild to moderate impacts in the Monteregie region, and was generally offset by the application of lime at an average rate of one ton per hectare every year. This rate is similar to the 0.3 to 0.9 tons/hectare/year rate concluded by Mehuys (1985). Using the corrective costs method, soil acidity costs are estimated at $30 per hectare per year, which is the cost of one ton of lime. In organic farming, nitrogen is provided by slow releasing natural compounds which are less damaging to soils. Additionally, since organic production on the typical farm utilizes lime on a yearly basis as part of the soil amendment practices, and the costs are included in the production budget, soil acidification costs will not be accounted for under environmental costs to avoid double counting.

Off-farm impacts of land degradation, which consist of negative impacts on neighboring fields, water bodies, as well as impacts on water-based recreation and navigation, are assumed to be equivalent to the average figures calculated by Fox and Dickson (1990) in their study of three watershed in south-western Ontario, which has somewhat a similar nature to the Monteregie area of Quebec. In this case, using the corrective/repair costs[158] to gullies and structures and the removal of sediments from waterways, the average costs of off-farm impacts are equal to $45.5 per hectare of land after adjusting for inflation.. This figure is close to the figure determined by Agriculture Canada (1986) for row crops in Canada. No off-farm impacts are assumed for organic production.

7.2.2.2. Water Pollution

Water contamination by agricultural chemicals is calculated based on the average amount of pesticides' active ingredients and fertilizers leached per hectare for the relevant drainage basins of the St-Lawrence River, as measured by Environment Canada (1999b). These values are equal to 2.4 kg active ingredients per hectare for pesticides, 60 kg per hectare for nitrogen fertilizers and 13.1 kg per hectare for phosphorous fertilizers. The costs of water pollution attributed to the typical farm are the portion of water treatment costs in Monteregie attributed to the typical farm based on the

[158] The use of the Benefits-Transfer method will produce same results between Quebec and Ontario since the equation parameters are almost identical.

proportional volume of chemicals active ingredients leached from the farm area. In discussions with specialists working in the water treatment plants in the Greater Montreal area, the average costs of water treatment and distribution using a combination of methods[159] was reported to be \$0.22 per cubic meter[160]. The total water treatment costs are calculated using Equations 6.10 & 6.11, as follows:

$$\text{Total municipal water Treatment costs in the Monteregie region (\$/year)} = \text{Average annual water consumption volume per capita in Canada (cubic meters/capita/year)} * \text{Population of the Monteregie region (capita)} * \text{Annual costs of municipal water (\$/cu. m.)}$$

$$= 0.34 \text{ cu.m./day} * 365 \text{ days} * 1{,}320{,}000 \text{ person} * \$0.22 / \text{cu.m.}$$
$$= \underline{\$36{,}038{,}640}$$

And

$$\text{Costs of water contamination attributed to the typical farm (\$/year)} = \frac{\text{Kgs of pesticides' active ingredients leached from the typical farm (kg a.i.)}}{\text{Kgs of pesticides' active ingredients leached from the Monteregie region}} * \text{Total municipal water treatment costs in the Monteregie region (\$/year)}$$

$$= \frac{16 \text{ ha} * 2.4 \text{ kg a.i./ha}}{1{,}105{,}900 \text{ ha} * 2.4 \text{ kg a.i./ha}} * \$36{,}038{,}640$$

$$= \underline{\$521.4}$$

The same costs will apply to nitrogen and phosphorous fertilizers since they all use the same farm area as a base for calculation, however, it will only be used once since the treatment process will treat the three compounds together. Organic production on the farm is assumed to cause no water pollution since it uses much less chemicals (and the chemicals are of natural origins that are less damaging). Fermented manure, if used properly is expected to cause insignificant damage. The costs per hectare of various crops are divided equally over various plots in the farm. The figures are shown in Tables 7.3A and 7.3B.

---

[159] Water treatment is done through a three-stage process of filtration, ozonation and chloronation.
[160] The water delivery costs will also be included as it represents part of water provision system.

Table 7.3A: Estimates of Total Environmental Costs for Conventional Production (1997-C$)

Impact	Year 1	Years 2-4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10*
Soil Erosion	0	0	0	11,841.4	15,451.0	19,060.5	22,670.1	42,279.6
Soil compaction	0	9,023.9	10,623.9	9,023.9	9,023.9	9,023.9	9,023.9	10,623.9
Soil acidity	480	480	480	480	480	480	480	480
Off-farm impacts	13,104	13,104	13,104	13,104	13,104	13,104	13,104	13,104
Water pollution	521.4	521.4	521.4	521.4	521.4	521.4	521.4	521.4
Total ($)	**14,105.4**	**23,129.3**	**24,729.3**	**34,970.7**	**38,580.3**	**42,189.8**	**45,799.4**	**67,009**

Notes: The same cycle of costs repeat for years 11-25.

Table 7.3B: Estimates of Total Environmental Costs for Organic Production (1997-C$)

Impact	Years 5,10,15,20, 25	All other years
Soil erosion	0	0
Soil compaction	1,600	0
Soil acidity	0	0
Off-farm	0	0
Water pollution	0	0
Total ($)	1,600	0

Under conventional production, soil erosion seems to cause the highest environmental damage followed by off-farm impacts and compaction. Organic production in the farm shows to be much less damaging to the environment.

7.2.3. Social Impacts

Social impacts consisted of two factors: benefits to the society/economy from creating additional on-farm jobs, and health costs from exposure to farm chemicals including the consumption of food and water with traces of (agricultural) chemical residues.

7.2.3.1. Health Impacts

The number of pesticide-related incidents was derived from the records of the Anti-Poison Center of Quebec. The plan was to consider the average of five years covering the period from 1993 to1997 as the base for future potential accidents. However, after more than one year of continuous demand of data, the center was unable to provide it for technical reasons. Therefore, the figures for 1997 were considered as the base for calculation, after receiving assurances that the incidents that took place in 1997 were to a large extent close to previous years, and that year 1997 did not witness any out-of-the-ordinary circumstances. The number of incidents attributed to the typical farm is assumed to be proportional to the volume of pesticides' active ingredients used on the farm over the total used in the province. This can be calculated using Equation 6.5. as follows:

$$\text{No. of pesticides-related accidents attributed to the typical farm} = \frac{\text{Kgs of pesticides' active ingredients used on farm}}{\text{Total kgs of pesticides' active ingredients used on agric. Lands in Quebec}} * \text{total number of accidents related to agriculture in Quebec}$$

$$= \frac{73.45 \text{ kgs}}{2,732,751 \text{ kgs}} * 517$$

$$= 0.013896 \ \underline{\text{accidents}}$$

The above number is almost zero, this is due to the small area of the farm relevant to the agricultural area in Quebec. Health costs are then calculated using the Costs of Illness Approach, which consists of direct and indirect costs. The direct ones include costs of medication and hospitalization, and the indirect costs include the value of lost wages due to absenteeism from work and value of lost leisure time. A discussion with medical experts from various hospitals in Quebec[161] in year 2000, indicated the standard type of treatment administered to patients (suspected of) or suffering from pesticides poisoning, as well as average hospitalization time and costs involved. While a Canadian resident may not directly pay for these costs, which are covered by the government-supported National Health Insurance Plan, the costs are borne by the society at large, which pays taxes to cover government expenditures including the medical bills. The total costs are equal to summation of the following (Equation 6.18):

A- Hospitalization and treatment costs:	$310 (hospital fees) + $100 (doctor's fees)
B- Costs of absenteeism (lost productivity/wages):	$8.72 (wage per hour) * 8 hours / day * 2 days
C- Cost of leisure time lost:	$ 46.5 (1/3 of lost wages)
Total :	$ 596.03 / case

The total cost for all the 517 cases is equal to $308,147.5. The portion of total health costs attributed to the typical farm can be measured using equation 6.19, as follows:

[161] Lakeshore Hospital (Pierrefonds) and Royal Victoria (Montreal).

$$\text{Health costs attributed to the typical farm (\$)} = \frac{\text{Kgs of pesticides' active ingredients applied to the typical farm (kg a.i.)}}{\text{Kgs of pesticides' active applied on agricultural lands in the province (kg a.i)}} * \begin{array}{c}\text{Total agricultural.} \\ \text{pesticides-related} \\ \text{health costs in the} \\ \text{province}\end{array}$$

$$= \frac{73.45 \text{ kgs}}{2{,}732{,}751 \text{ kgs}} * \$308{,}147.5$$

$$= \underline{\$ 8.28}$$

The figure related to the farm is insignificant due to the small volume of chemicals applied on the farm compared to overall volume of chemicals applied in the province. There were also 28 reported cases related to organic chemicals. Since figures on the total usage of organic chemicals in the province is not available, the percentage attributed to the typical farm will be assumed to be proportional to the total organic farmland area in Quebec (13,000). Therefore the total costs of health impacts related to organic farming on the farm is equivalent to $20.54.

7.2.3.2. <u>Impacts on Employment</u>

Based on the production plan discussed in Appendix A, the typical farm required around 5800.46 hours of labor for the season extending from May to the end of December. After deducting the hours put in by the farm operator, who considers himself to be self employed, and assuming a monthly working work load of 208 hours per worker, the total number of workers needed on the organic farm is about 2.98 per month over seven months[162], with a gross monthly salary of $1,813.76 per worker. Similarly, using the figures reported in CREAQ, the conventional production required 3,207.7 hours, which is equivalent to creating 1.2 on-farm jobs per month over 7 months.

The direct benefits from the jobs created can be calculated using Equations 6.12 and 6.13 as follows:

$$\begin{array}{c}\text{Direct Benefits} \\ \text{to the economy}\end{array} = \text{net wages} + \begin{array}{c}\text{reduced transfer} \\ \text{payments}\end{array} + \begin{array}{c}\text{increased govern-} \\ \text{-mental taxes}\end{array} + \begin{array}{c}\text{import} \\ \text{effects}\end{array}$$

[162] The numbers will not be rounded since labors can be hired per hour.

$= L*W + L*WP + L*W*t - \Delta Yd*mpm$

Given that:

Welfare payments (WP) = $750/person/month
Tax rate (t) = 20% on revenues beyond the $750/month (=$212.75 in this case)
Change in disposable income (ΔYd) = ($1813.76 –$212.75 - $750) = $851/person
Marginal propensity to import (mpm) = 0.72

Therefore the direct benefits to the economy from creating these jobs are equal to:

For Organic= 20.88 jobs-month*$1601/month + 20.88 jobs-month * $750/ month + 20.88*212.75 -20.88*($851)*0.72

= <u>$40,750.91</u>

For Conventional = 8.42*1601 + 8.42*750+8.42*212.75- 851*8.42*0.72

= <u>$16,431</u>

The indirect benefits to the economy from creating these jobs can be calculated using (part of the) Keynesian model to reflect the impact on the GDP. This can be illustrated using equations 6.14 to 6.17, as follows:

$$\text{Total}\Delta GDP = \Delta GDP_c + \Delta GDP_t + \Delta GDP_g$$

The first component; ΔGDPc, reflects the change in GDP as a result of increased workers consumption. This can be calculated by multiplying the change in the net amount of money available for consumption as a result of increased disposable income by the adjusted Spending Multiplier, as follows:

$$\Delta GDP_c = \Delta C * SMm$$

With

SMm = 1/{1-mpc(1-t)+mpm} = 1/{1-0.795(1-0.2)+0.72) = 0.92 [163]

ΔC[164] = Δ Yd * mpc = [(New season salary – taxes – old net season salary) per worker)] * No. of workers * mpc

= $851* 20.88 * 0.795

= <u>$14,131</u>

[163] Mpc and mpm were derived from statistics on consumption, disposable income and imports reported by the Statistics Institute of Quebec (Institut de la Statistique du Quebec), 2001.

[164] The change in consumption is equivalent to mpc multiplied by the change in real disposable income.

Therefore ΔGDPc for organic production is equal to <u>$13,036.</u> The above equation assumed an income tax rate of 20% on revenues exceeding $750 per month. Similarly, the equation produced a value of <u>$5,256.2</u> for conventional production.

The second component, ΔGDPt, reflects the change in GDP as a result of increased taxes paid by the newly employed. This can be calculated by multiplying the change in tax revenues by the adjusted Tax Multiplier, as follows:

$$\Delta GDP_t = \Delta T * TMm$$

With

TMm = -mpc (1-t)/{1-mpc(1-t)+mpm} = -0.733

ΔT = Additional tax payments per worker per season * No. of workers

= ($212.75) * 20.88

= <u>$4,443.71</u>

Therefore ΔGDPt is equal to -<u>$3,258.98.</u> The above equation assumed that an unemployed worker used to receive $750 per month as welfare payment and the tax rate is equal to 20% on revenues exceeding $750 per month. Similarly, the equation produced a value of -<u>$1314.04</u> for conventional production.

The third component, ΔGDPg, reflects the change in GDP as a result of decreased governmental transfer payments. This can be calculated by multiplying the change in net government expenditures by the adjusted Spending Multiplier, as follows:

$$\Delta GDPg = \Delta G * SMm$$

With

SMm = 1/{1-mpc(1-t)+mpm} = 1/{1-0.795(1-0.2)+0.72) = 0.92

ΔG = Seasonal welfare payments saved by the government per worker * No. of workers

= (0–750)* 20.88 workers

= - <u>$15,665</u>

Therefore ΔGDPg is equal to - $14,451.2. The above equation used a tax rate of 20%. Similarly, the equation produced a value of - $5,826.8 for conventional production. The total employment benefits to the GDP, consisting of the three above-mentioned components are shown in Table 7.4.

Table 7.4: Employment Benefits

	Direct Benefits	Indirect Benefits	Total Benefits
Organic Production	40,750.91	-4,674.23	**36,076.69**
Convent. Production	16,431.09	-1,884.68	**14,546.40**

However, given the uncertainty and magnitude of the employment benefit estimates, the analysis will include a scenario that excludes these figures (Tables 7.10B and 7.10C). With all components calculated, the cash flow can be prepared.

7.3. Cash Flow and CBA Results

Cash flow analysis includes the consideration of depreciation and taxes in addition to the variables listed in the above sections, for all the years under analysis. Cash flow analysis will be performed for four scenarios, representing conventional and organic production systems under conventional and extended analysis. The four scenarios are listed in Figure 7.1.

Figure 7.1: The Comparison Cases

	Conventional Production (C)	**Organic Production (O)**
Conventional CBA (CC)	**Case 1**	**Case 2**
Extended CBA (EC)	**Case 3**	**Case 4**

The Conventional analysis considered only the private financial costs and benefits at a market interest rate of 8%, while the extended analysis included, in addition to the financial net returns, social and environmental impacts at a lower-than-market discount rate, which in this case, was 4%. Two additional assumptions were made: 1) interest is calculated on an annual basis; and 2) cash flows for years 1 to 25 are assumed to occur at the end of each year. A corporate tax rate of 0% was used for this study as the analysis is more concerned about the net economic returns to the society, than to the financial returns to the farmer. However, for comparison purposes, NPV will also be calculated for the four scenarios using a corporate tax rate of 20%, which will be applied to the net private inflows incurred on the farm (i.e. on-farm costs of soil degradation). Cash flow analysis using the Bottom-Up Approach are listed in Tables 7.5A, 7.5B, 7.5C and 7.5D and the summary of the results is shown in Table 7.6.

Table 7.5A: Cash Flow for Conventional Production Using Conventional Analysis - Case 1

	Year																									
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
REVENUES ($)																										
Total Farm Revenues	0	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478
TOTAL REVENUES	**0**	**180,478**	**180,478**	**180,478**	**180,478**	**180,478**	**180,478**	**180,478**	**180,478**	**180,478**	**180,478**	**180,478**	**180,478**	**180,478**	**180,478**	**180,478**	**180,478**	**180,478**	**180,478**	**180,478**	**180,478**	**180,478**	**180,478**	**180,478**	**180,478**	**180,478**
COSTS ($)																										
Economic																										
Capital expenditures	400,450																									
Total depreciation	0	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045
Total operating costs	0	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916
TOTAL COSTS	**400,450**	**120,961**	**120,961**	**120,961**	**120,961**	**120,961**	**120,961**	**120,961**	**120,961**	**120,961**	**120,961**	**120,961**	**120,961**	**120,961**	**120,961**	**120,961**	**120,961**	**120,961**	**120,961**	**120,961**	**120,961**	**120,961**	**120,961**	**120,961**	**120,961**	**120,961**
Eearnings before tax	-400,450	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517
Tax rate	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total taxes (@0%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Net income	-400,450	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517	59,517
+ Depreciation	0	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045
Net salvage value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	308,786
New Capital investments		0	0	0	0	0	0	0	0	0	225,450	0	0	0	0	0	0	0	0	0	315,450	0	0	0	0	0
NET CASH FLOW	-400,450	86,562	86,562	86,562	86,562	86,562	86,562	86,562	86,562	86,562	-138,888	86,562	86,562	86,562	86,562	86,562	86,562	86,562	86,562	86,562	-228,888	86,562	86,562	86,562	86,562	395,348

Table 7.5B: Cash Flow for Organic Production Using Conventional Analysis - Case 2

	Year												
	0	1	2	3	4	5	6	7	8	9	10	11	12
REVENUES ($)													
Total Farm Revenues	0	127,560	127,560	127,560	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037
TOTAL REVENUES	0	127,560	127,560	127,560	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037
COSTS ($)													
Economic													
Capital expenditures	404,100												
Total depreciation	0	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410
Total operating costs	0	125,922	125,922	125,922	131,774	131,774	131,774	131,774	131,774	131,774	131,774	131,774	131,774
TOTAL COSTS	404,100	153,332	153,332	153,332	159,184	159,184	159,184	159,184	159,184	159,184	159,184	159,184	159,184
Eearnings before tax	-404,100	-25,772	-25,772	-25,772	120,853	120,853	120,853	120,853	120,853	120,853	120,853	120,853	120,853
Tax rate	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total taxes (@0%)	0	0	0	0	0	0	0	0	0	0	0	0	0
Net income	-404,100	-25,772	-25,772	-25,772	120,853	120,853	120,853	120,853	120,853	120,853	120,853	120,853	120,853
+ Depreciation	0	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410
Net salvage value	0	0	0	0	0	0	0	0	0	0	0	0	0
New capital investments		0	0	0	0	0	0	0	0	0	229,100	0	0
NET CASH FLOW	-404,100	1,638	1,638	1,638	148,263	148,263	148,263	148,263	148,263	148,263	-80,837	148,263	148,263

	Year												
	13	14	15	16	17	18	19	20	21	22	23	24	25
REVENUES ($)													
Total Farm Revenues	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037
TOTAL REVENUES	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037
COSTS ($)													
Economic													
Capital expenditures													
Total depreciation	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410
Total operating costs	131,774	131,774	131,774	131,774	131,774	131,774	131,774	131,774	131,774	131,774	131,774	131,774	131,774
TOTAL COSTS	159,184	159,184	159,184	159,184	159,184	159,184	159,184	159,184	159,184	159,184	159,184	159,184	159,184
Eearnings before tax	120,853	120,853	120,853	120,853	120,853	120,853	120,853	120,853	120,853	120,853	120,853	120,853	120,853
Tax rate	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total taxes (@0%)	0	0	0	0	0	0	0	0	0	0	0	0	0
Net income	120,853	120,853	120,853	120,853	120,853	120,853	120,853	120,853	120,853	120,853	120,853	120,853	120,853
+ Depreciation	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410
Net salvage value	0	0	0	0	0	0	0	0	0	0	0	0	310,611
New capital investments	0	0	0	0	0	0	0	319,100	0	0	0	0	0
NET CASH FLOW	148,263	148,263	148,263	148,263	148,263	148,263	148,263	-170,837	148,263	148,263	148,263	148,263	458,874

Table 7.5C: Cash Flow for Conventional Production Using Extended Analysis - Case 3

	Year 0	1	2	3	4	5	6	7	8	9	10	11	12
REVENUES ($)													
Total Farm Revenues	0	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478
Contribution from On-Farm Employment	0	14,546	14,546	14,546	14,546	14,546	14,546	14,546	14,546	14,546	14,546	14,546	14,546
TOTAL REVENUES	**0**	**195,025**	**195,025**	**195,025**	**195,025**	**195,025**	**195,025**	**195,025**	**195,025**	**195,025**	**195,025**	**195,025**	**195,025**
COSTS ($)													
Economic													
Capital expenditures	400,450												
Total depreciation	0	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045
Total operating costs	0	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916
Environmental													
Soil Erosion	0	0	0	0	0	0	11,841	15,451	19,061	22,670	42,280	0	0
Soil Compaction	0	0	9,024	9,024	9,024	10,624	9,024	9,024	9,024	9,024	10,624	9,024	9,024
Soil Acidity	0	480	480	480	480	480	480	480	480	480	480	480	480
Off-farm	0	13,104	13,104	13,104	13,104	13,104	13,104	13,104	13,104	13,104	13,104	13,104	13,104
Water Pollution	0	521	521	521	521	521	521	521	521	521	521	521	521
Social													
Health-Related	0	8	8	8	8	8	8	8	8	8	8	8	8
TOTAL COSTS	400,450	135,075	144,099	144,099	144,099	145,699	155,940	159,550	163,160	166,769	187,979	144,099	144,099
Earnings before tax	-400,450	59,949	50,926	50,926	50,926	49,326	39,084	35,475	31,865	28,255	7,046	50,926	50,926
Tax rate	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total taxes (@0%)	0	0	0	0	0	0	0	0	0	0	0	0	0
Net income	-400,450	59,949	50,926	50,926	50,926	49,326	39,084	35,475	31,865	28,255	7,046	50,926	50,926
+ Depreciation	0	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045
Net salvage value	0	0	0	0	0	0	0	0	0	0	0	0	0
New Capital investments		0	0	0	0	0	0	0	0	0	225,450	0	0
NET CASH FLOW	-400,450	86,994	77,971	77,971	77,971	76,371	66,129	62,520	58,910	55,300	-191,359	77,971	77,971

	Year 13	14	15	16	17	18	19	20	21	22	23	24	25
REVENUES ($)													
Total Farm Revenues	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478	180,478
Contribution from On-Farm Employment	14,546	14,546	14,546	14,546	14,546	14,546	14,546	14,546	14,546	14,546	14,546	14,546	14,546
TOTAL REVENUES	**195,025**	**195,025**	**195,025**	**195,025**	**195,025**	**195,025**	**195,025**	**195,025**	**195,025**	**195,025**	**195,025**	**195,025**	**195,025**
COSTS ($)													
Economic													
Capital expenditures													
Total depreciation	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045
Total operating costs	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916	93,916
Environmental													
Soil Erosion	0	0	0	11,841	15,451	19,061	22,670	42,280	0	0	0	0	0
Soil Compaction	9,024	9,024	10,624	9,024	9,024	9,024	9,024	10,624	9,024	9,024	9,024	9,024	10,624
Soil Acidity	480	480	480	480	480	480	480	480	480	480	480	480	480
Off-farm	13,104	13,104	13,104	13,104	13,104	13,104	13,104	13,104	13,104	13,104	13,104	13,104	13,104
Water Pollution	521	521	521	521	521	521	521	521	521	521	521	521	521
Social													
Health-Related	8	8	8	8	8	8	8	8	8	8	8	8	8
TOTAL COSTS	144,099	144,099	145,699	155,940	159,550	163,160	166,769	187,979	144,099	144,099	144,099	144,099	145,699
Earnings before tax	50,926	50,926	49,326	39,084	35,475	31,865	28,255	7,046	50,926	50,926	50,926	50,926	49,326
Tax rate	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total taxes (@0%)	0	0	0	0	0	0	0	0	0	0	0	0	0
Net income	50,926	50,926	49,326	39,084	35,475	31,865	28,255	7,046	50,926	50,926	50,926	50,926	49,326
+ Depreciation	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045	27,045
Net salvage value	0	0	0	0	0	0	0	0	0	0	0	0	308,786
New Capital investments	0	0	0	0	0	0	0	315,450	0	0	0	0	0
NET CASH FLOW	77,971	77,971	76,371	66,129	62,520	58,910	55,300	-281,359	77,971	77,971	77,971	77,971	385,157

Table 7.5D: Cash Flow for Organic Production Using Extended Analysis - Case 4

	Year																									
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
REVENUES ($)																										
Total Farm Revenues	0	127,560	127,560	127,560	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037	280,037
Contrib from On-Farm Employment	0	36,077	36,077	36,077	36,077	36,077	36,077	36,077	36,077	36,077	36,077	36,077	36,077	36,077	36,077	36,077	36,077	36,077	36,077	36,077	36,077	36,077	36,077	36,077	36,077	36,077
TOTAL REVENUES	**0**	**163,637**	**163,637**	**163,637**	**316,113**	**316,113**	**316,113**	**316,113**	**316,113**	**316,113**	**316,113**	**316,113**	**316,113**	**316,113**	**316,113**	**316,113**	**316,113**	**316,113**	**316,113**	**316,113**	**316,113**	**316,113**	**316,113**	**316,113**	**316,113**	**316,113**
COSTS ($)																										
Economic																										
Capital expenditures	404,100																									
Total depreciation	0	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410
Total operating costs	0	125,922	125,922	125,922	131,774	131,774	131,774	131,774	131,774	131,774	131,774	131,774	131,774	131,774	131,774	131,774	131,774	131,774	131,774	131,774	131,774	131,774	131,774	131,774	131,774	131,774
Environmental																										
Soil Erosion	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Soil Compaction	0	0	0	0	0	1,600	0	0	0	0	1,600	0	0	0	0	1,600	0	0	0	0	1,600	0	0	0	0	1,600
Soil Acidity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Off-farm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water Pollution	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Social																										
Health-Related	0	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
TOTAL COSTS	404,100	153,352	153,352	153,352	159,205	160,805	159,205	159,205	159,205	159,205	160,805	159,205	159,205	159,205	159,205	160,805	159,205	159,205	159,205	159,205	160,805	159,205	159,205	159,205	159,205	160,805
Earnings before tax	-404,100	10,284	10,284	10,284	156,909	155,309	156,909	156,909	156,909	156,909	155,309	156,909	156,909	156,909	156,909	155,309	156,909	156,909	156,909	156,909	155,309	156,909	156,909	156,909	156,909	155,309
Tax rate	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total taxes (@0%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Net Income	-404,100	10,284	10,284	10,284	156,909	155,309	156,909	156,909	156,909	156,909	155,309	156,909	156,909	156,909	156,909	155,309	156,909	156,909	156,909	156,909	155,309	156,909	156,909	156,909	156,909	155,309
+ Depreciation	0	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410	27,410
Net salvage value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	310,611
New capital investments		0	0	0	0	0	0	0	0	0	229,100	0	0	0	0	0	0	0	0	0	319,100	0	0	0	0	0
NET CASH FLOW	**-404,100**	**37,694**	**37,694**	**37,694**	**184,319**	**182,719**	**184,319**	**184,319**	**184,319**	**184,319**	**-46,381**	**184,319**	**184,319**	**184,319**	**184,319**	**182,719**	**184,319**	**184,319**	**184,319**	**184,319**	**-136,381**	**184,319**	**184,319**	**184,319**	**184,319**	**493,330**

Table 7.6: Results of Analysis

	Conventional CBA				Extended CBA			
	NPV	PI	IRR	DPB	NPV	PI	IRR	DPB
Conventional Production	396,559	1.14	19.22%	7.58	507,995	1.1	15.09%	6.10
Organic Production	671,480	1.24	19.22%	8.47	1,879,942	1.57	25.76%	5.05

The analysis has shown that in comparing conventional and organic production systems under conventional CBA analysis, that is from a private, farm operator perspective, organic production had higher NPV values (by 69.33%), and therefore was more profitable to the farm operator[165]. This was expected given the higher annual net returns of organic production. If the two projects were considered to be independent, then both projects would be implemented as they had positive NPV. If the two production systems were mutually exclusive, i.e. only one to be chosen, the organic production system would be preferred. This conclusion was also supported by the profitability index (PI). The internal rate of return (IRR) coincidently produced somewhat similar values, which can be attributed to numerical reasons. The discounted payback period, however, was higher for organic production due to the different timing of cash flows between the two systems (and given the reduced revenues during organic transition).

In comparing the two production systems under the extended analysis, which considers societal perspectives, organic production has shown to be much more profitable to the society than conventional production[166]. Environmental and social impacts were larger in the conventional production and have, therefore, affected the results. This can be seen in about four times the value of NPV, higher PI, IRR and lower discounted payback period, for the organic system. This reflects how results of analysis can show an improved picture when the analysis is done in a different manner.

The conventional production was less profitable under conventional analysis than under the extended analysis (NPV 396,559 < NPV 507,995). This result can be attributed to the use of a lower discount rate (i.e. 4% instead of 8%) under the extended analysis. However, using the same discount rate (i.e. 4% or 8%), the conventional production becomes less profitable under the extended analysis since the analysis considers the

[165] In financial terms, the project would maximize shareholders' wealth.

[166] In economic terms, the project could maximize society's wealth and welfare.

many associated negative environmental and social impacts that were previously excluded under conventional analysis (Tables 7.7A and 7.7B).

On the other hand, organic production was shown to be more profitable under the extended analysis than under conventional analysis (NPV 1,879,942 > NPV 671,480). This is because its environmentally conservative practices and social benefits have been adequately accounted for.

It was also shown that when the organic production system discussed in this research, was evaluated under an extended analysis, it was shown to be more beneficial than the conventional system under the conventional analysis. This comparison will help to support the conviction that conversion to sustainable farming practices is, in general, better from a societal perspective. However, this conclusion is to be further investigated with additional studies. Additionally, if organic production is to be adopted on a large scale in the province, there are other factors that need to be considered, such as the overall effect on supply and demand and its subsequent effect on prices and costs of inputs, trade balance and governmental subsidy programs.

One of the main issues affecting the conversion to organic by farmers is the price premium they receive on their produce. If this was removed, then the NPV for organic production under conventional analysis is equal to -\$563,227, which is a large loss. However, under the extended analysis, where social and environmental impacts are accounted for, the loss decreases to -\$78,923. This reflects the importance of considering also the societal (non-financial) impacts as it widely affects the results. The results of analysis are shown in Table 7.6B. While, it is unlikely that the organic premium is eliminated in the short run due to the large gap between the demand and the quantity supplied, the profitability of the organic system is evaluated under various premium rates using the standard and extended CBA analysis in the sensitivity analysis.

Table 7.6B: Results of Analysis for Organic Production with No Price Premium

	Conventional CBA				**Extended CBA**			
	NPV	**PI**	**IRR**	**DPB**	**NPV**	**PI**	**IRR**	**DPB**
Organic Production	-563,227	0.65	-9.72%	Over 25	-78,923	0.89	2.27%	Over 25

The four scenarios (with the price premium) were also compared from a financial perspective, i.e. when a corporate tax of 20% was included. The tax was applied on net inflows incurred by the farmer, which affect his profitability but not the society's. The results are shown in Table 7.6C, which shows that an extended CBA analysis provides a better picture of the situation. The results of comparison between the two production methods under the two analysis systems are similar to the results reached by the no corporate-tax calculations discussed above.

Table 7.6C: Results of Analysis with a 20% Corporate Tax on Net Private Inflows

	Conventional CBA				Extended CBA			
	NPV	PI	IRR	DPB	NPV	PI	IRR	DPB
Conventional Production	269,493	1.14	15.76%	9.38	377,569	1.1	12.23%	10.51
Organic Production	489,038	1.24	16.90%	8.05	1,584,651	1.57	23.88%	6.68

In calculating the Cross-Over Rate, i.e. the rate after which one of the production systems becomes more profitable than the other, it was noticed that the organic system becomes less profitable than the conventional system when the discount rate increases above 19.22% under conventional analysis. The latter discount rate is unlikely to occur in Canada given the prevailing economic conditions. Under an extended analysis, the Cross-Over Rate for the organic system to become less favorable is even higher, 50.34%. This again indicates not only the strong performance of this organic system under both analysis, but also how the extended analysis yields different results. The above results can be concluded from the NPV profiles of both production systems shown in Figures 7.2 and 7.3.

Figure 7.2: Graphical Illustration of the NPV Profiles and the Cross-Over Rates for Both Production Systems under Conventional Analysis

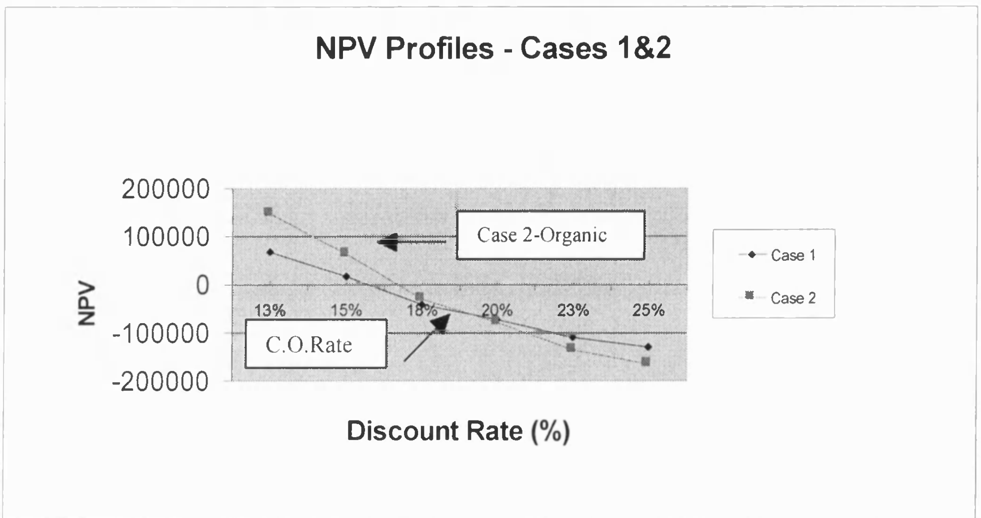
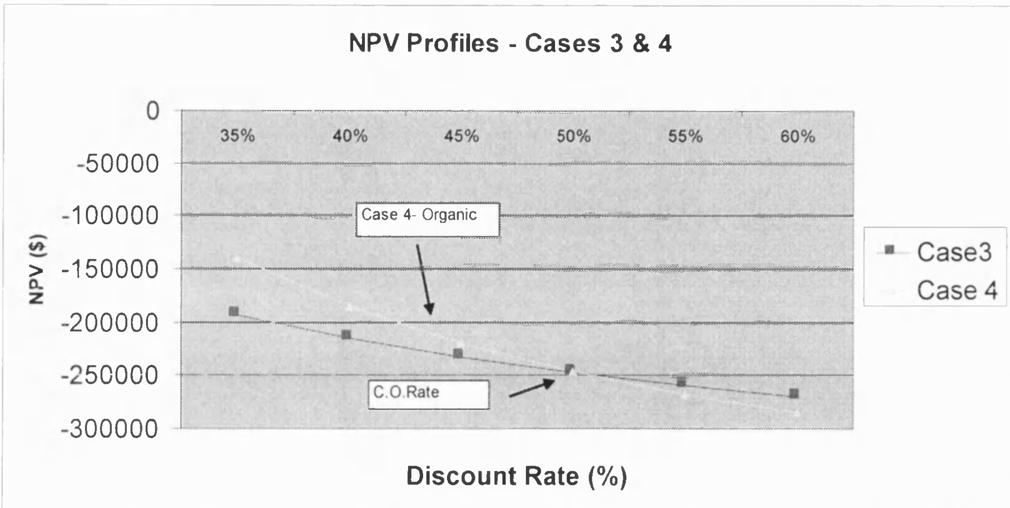


Figure 7.3: Graphical Illustration of the NPV Profiles and the Cross-Over Rates for Both Production Systems under Extended Analysis



7.4. Sensitivity Analysis

A sensitivity analysis was conducted to determine how sensitive the results of the analysis were to a range of possible variations in the values of the studied parameters. The analysis considered changes to the discount rate, values of various impacts and years of analysis, with the results discussed in the following subsections. The results will show if a certain variable is likely to be significant for profitability. Therefore such analysis is expected to be of high importance for improved decision-making.

7.4.1. Discount Rates

The NPV, PI and DPB were calculated for both production systems under conventional and extended analysis, for discount rates that are most likely to occur. Higher rates reflect stronger risk aversion and a higher cost of capital. The results are presented in Tables 7.7A and 7.7B.

Table 7.7A: Results of Analysis at Different Discount Rates under Conventional CBA Analysis

	Conventional CBA Analysis					
Discount Rate (%)	Conventional Production			Organic Production		
	NPV	PI	DPB	NPV	PI	DPB
0%	1,531,479	1.32	4.37	2,625,004	1.50	5.31
1%	1,284,071	1.30	5.23	2,203,178	1.47	6.16
2%	1,080,512	1.28	5.09	1,854,291	1.44	6.02
3%	911,927	1.25	6.79	1,564,075	1.41	7.71

4%	771,382	1.23	6.62	1,321,285	1.37	7.53
5%	653,435	1.21	6.45	1,117,022	1.34	7.37
6%	553,797	1.19	6.29	944,212	1.31	7.21
7%	469,072	1.16	6.14	797,208	1.28	7.07
8%	**396,559**	**1.14**	**7.58**	**671,480**	**1.24**	**8.47**
9%	334,100	1.12	7.41	563,381	1.21	8.31
10%	279,963	1.09	7.24	469,961	1.18	8.15
11%	232,753	1.07	7.09	388,821	1.15	8.00
12%	191,339	1.05	8.34	318,005	1.12	9.23

Standard Deviation	**425,314**	**733,470**
Mean	**668,491**	**1,141,379**
Coefficient of Variation	**0.64**	**0.64**

The results presented in Table 7.7A show that, as expected, NPV for both production systems decrease with increasing discount rates[167]. The NPV remained positive[168] but varied widely from $1.53 million to $191 thousands for conventional production and from 2.6 million to $318 thousands for the organic production. This shows that both projects remain feasible at considerable variations in discount rates. This conclusion is confirmed by the values of the PI ratio and DPB. The PI ratios remained above one for all the above rates. The values of DPB implied that the project's cumulative discounted returns were able to pay for its cumulative discounted costs within its life span at the above rates. The superiority of this organic system can also be seen at a zero discount rate. NPV and PI for the organic system were better (higher) but the DPB period was higher (longer period was needed). The latter can be attributed to the different values of costs and benefits for each system.

Looking at the coefficient of variation for both production systems, Table 7.7A shows that the results of the analysis were somewhat similar (0.64) and therefore, have similar risk at different discount rates.

[167] This is due to the nature of the mathematical formula of discounting, which reduces the value of discounted cash flow at higher discount rates.

[168] The values of NPVwill remain positive until the rate reaches the value of the IRR.

Table 7.7B: Results of Analysis at Different Discount Rates under Extended CBA Analysis

Discount Rate (%)	Extended CBA Analysis: Conventional Production			Extended CBA Analysis: Organic Production		
	NPV	PI	DPB	NPV	PI	DPB
0%	1,095,118	1.15	5.95	3,518,407	1.70	4.42
1%	902,226	1.14	6.72	2,990,340	1.67	5.32
2%	744,720	1.13	6.50	2,552,230	1.64	5.22
3%	615,218	1.11	6.29	2,186,679	1.60	5.13
4%	**507,995**	**1.10**	**6.10**	**1,879,942**	**1.57**	**5.05**
5%	418,585	1.08	8.57	1,621,114	1.53	6.71
6%	343,495	1.06	8.36	1,401,502	1.50	6.59
7%	279,979	1.05	8.17	1,214,149	1.46	6.48
8%	225,868	1.03	9.21	1,053,460	1.43	6.37
9%	179,443	1.02	10.21	914,920	1.39	6.27
10%	139,332	1.00	11.18	794,865	1.36	6.18

	Conventional	Organic
Standard Deviation	312,488	892,572
Mean	495,634	1,829,783
Coefficient of Variation	0.63	0.49

Under the extended analysis (results in Table 7.7B), both production systems remained feasible over the above range of discount rates if the NPV criterion was used (the conventional production became economically unfeasible at rates over 15.09%). The PI showed that the conventional system was not feasible at rates over 10% and the DPB showed that the conventional system's cumulative returns were sufficient to pay back its cumulative costs within its lifetime at the above discount rates. The organic system remained feasible over the above range of discount rates and showed better performance using the three criteria at the above discount rates.

The superiority of this organic system can also be seen at a zero discount rate using the three criteria. The extended analysis has better revealed the superiority of the organic system over the conventional since it accounted for the environmental and social externalities of the organic system. If the same rate of either 8% or 4% were used for both analysis, the results would still favor the organic over the conventional production system. Additionally, the lower discount rate of 4%, used in the extended analysis, has helped to decrease the effects/values of remote environmental and social costs. Table 7.7B also showed that the results of the analysis of the organic system showed to be less risky to fluctuations in discount rates since its coefficient of variation (0.49) was lower than that of the conventional system (0.63). This conclusion was not properly deduced from the results of the standard CBA analysis.

7.4.2. Different Years

Project feasibility was checked under various years of analysis since cash flows differed with time, especially as additional capital investments were needed to replace depreciated machinery, equipment and farm structures. NPV was calculated for various intervals of time, namely 10, 15 and 20 years[169], and the results are listed in Tables 7.8A and 7.8B.

Table 7.8A: NPV under Various Years of Analysis and Discount Rates - Conventional Analysis

	Conventional Production				Organic Production			
	Years of Analysis				Years of Analysis			
Discount Rate (%)	10	15	20	25	10	15	20	25
0%	835,509	916,270	1,538,829	1,531,479	1,012,645	1,625,535	2,329,324	2,625,004
1%	754,668	805,584	1,312,775	1,284,071	907,490	1,431,870	1,991,019	2,203,178
2%	680,907	707,962	1,121,740	1,080,512	811,638	1,260,579	1,703,603	1,854,291
3%	613,508	621,612	959,629	911,927	724,152	1,108,728	1,458,494	1,564,075
4%	551,832	545,013	821,487	771,382	644,202	973,801	1,248,677	1,321,285
5%	495,314	476,869	703,273	653,435	571,049	853,644	1,068,393	1,117,022
6%	443,449	416,075	601,681	553,797	504,032	746,402	912,907	944,212
7%	395,786	361,683	514,002	469,072	442,564	650,480	778,311	797,208
8%	**351,926**	**312,884**	**438,004**	**396,559**	**386,120**	**564,499**	**661,370**	**671,480**
9%	311,510	268,981	371,849	334,100	334,228	487,268	559,399	563,381
10%	274,217	229,375	314,014	279,963	286,467	417,752	470,161	469,961
11%	239,761	193,548	263,237	232,753	242,459	355,054	391,791	388,821
12%	207,883	161,052	218,468	191,339	201,865	298,394	322,726	318,005
Standard Deviation	**202,526**	**242,539**	**421,396**	**425,314**	**261,683**	**426,686**	**641,230**	**733,470**
Mean	**473,559**	**462,839**	**706,076**	**668,491**	**543,762**	**828,770**	**1,068,937**	**1,141,37**
Coefficient of Variation	**0.43**	**0.52**	**0.60**	**0.64**	**0.48**	**0.51**	**0.60**	**0.64**

The above table shows that for the conventional production, NPV values were highest for a project life of 20 years at discount rates from 1 to 12%. This was followed by projects lasting for 25 years. Projects lasting for 15 years were more favorable than 10 years projects at discount rates below 4%, but the ranking was reversed at higher

[169] A five years period was not considered since organic production required three years to get certified.

discount rates. The above results can be attributed to the structure and timing of cash flows, which had some capital investments fully depreciated at 10 and 20 years. When projects ended at that dates, the overall profitability seemed to increase. For organic production, the NPV values were higher the longer the project life was, at discount rates that were below 10%. At these rates, the higher annual gross margins of organic production seem to have offset the additional investment needed for machinery replacement. However, at rates higher than 9%, the preference was for projects lasting for 20 years.

The results were somewhat similar under the extended analysis (Table 7.8B), with the 20-year projects mostly favored for the conventional and organic production systems. Conventional and organic productions seemed to be less profitable to the society at 10 and 15 years, and more profitable when adopted for longer periods at various discount rates.

Table 7.8B: NPV under Various Years of Analysis and Discount Rates - Extended Analysis

	Conventional Production				Organic Production			
	Years of Analysis				Years of Analysis			
Discount Rate (%)	10	15	20	25	10	15	20	25
0%	644,118	680,323	1,147,023	1,095,118	1,370,006	2,161,578	3,273,147	3,518,407
1%	577,090	588,881	966,350	902,226	1,246,018	1,927,441	2,843,413	2,990,340
2%	515,934	508,581	814,174	744,720	1,132,753	1,719,924	2,476,087	2,552,230
3%	460,052	437,853	685,469	615,218	1,029,147	1,535,566	2,160,907	2,186,679
4%	**408,914**	**375,368**	**576,155**	**507,995**	**934,254**	**1,371,403**	**1,889,449**	**1,879,942**
5%	362,046	319,997	482,914	418,585	847,229	1,224,889	1,654,771	1,621,114
6%	319,031	270,782	403,037	343,495	767,320	1,093,832	1,451,141	1,401,502
7%	279,495	226,905	334,307	279,979	693,854	976,342	1,273,806	1,214,149
8%	243,104	187,670	274,906	225,868	626,229	870,787	1,118,815	1,053,460
9%	209,561	152,478	223,339	179,443	563,908	775,750	982,873	914,920
10%	178,601	120,820	178,372	139,332	506,406	690,004	863,224	794,865
Standard Deviation	**153,879**	**184,355**	**318,057**	**312,488**	**285,540**	**485,467**	**792,462**	**892,572**
Mean	**381,632**	**351,787**	**553,277**	**495,634**	**883,375**	**1,304,320**	**1,817,058**	**1,829,783**
Coefficient of Variation	**0.40**	**0.52**	**0.57**	**0.63**	**0.32**	**0.37**	**0.44**	**0.49**

The analysis also showed that organic systems under various years had lower coefficient of variation, and therefore, were, in general, less sensitive to fluctuations in discount rates than the conventional systems under the extended analysis. These results were somewhat similar under conventional analysis. The rankings are shown in Table 7.9.

Table 7.9 : Ranking of Projects with various Years under the Two Analysis

	Conventional Analysis								Extended Analysis							
	Conventional Production				Organic Production				Conventional Production				Organic Production			
	Years of Analysis								Years of Analysis							
Discount Rate (%)	10	15	20	25	10	15	20	25	10	15	20	25	10	15	20	25
0%	4	3	1	2	4	3	2	1	4	3	1	2	4	3	2	1
1%	4	3	1	2	4	3	2	1	4	3	1	2	4	3	2	1
2%	4	3	1	2	4	3	2	1	3	4	1	2	4	3	2	1
3%	4	3	1	2	4	3	2	1	3	4	1	2	4	3	2	1
4%	3	4	1	2	4	3	2	1	3	4	1	2	4	3	1	2
5%	3	4	1	2	4	3	2	1	3	4	1	2	4	3	1	2
6%	3	4	1	2	4	3	2	1	3	4	1	2	4	3	1	2
7%	3	4	1	2	4	3	2	1	3	4	1	2	4	3	1	2
8%	3	4	1	2	4	3	2	1	2	4	1	3	4	3	1	2
9%	3	4	1	2	4	3	2	1	2	4	1	3	4	3	1	2
10%	3	4	1	2	4	3	1	2	1	4	2	3	4	3	1	2
11%	2	4	1	3	4	3	1	2								
12%	2	4	1	3	4	3	1	2								

7.4.3. Different Values of Variables

The analysis investigated the changes in the values of NPV under various changes in different variables, namely, sales revenues, social benefits, total operating costs, total environmental costs and social costs and benefits under the two CBA analysis methods. Special attention is made to changes in the price premiums received by the organic produce. The results are shown in Tables 7.10 and 7.11.

Table 7.10: The Marginal Effect on NPV From a 10% Change in Various Variables

	Total Sales Revenues (TSR)	Total Operating Costs (TOC)	Total Employment Benefits (TEB)	Total Environmental Costs (TEC)	Total Health Costs (THC)
Case 1 (convent., conv. CBA)	192,656	-100,254			
Case 2 (organic, conv. CBA)	259,638	-139,158			
Case 3 (convent, ext CBA)	281,944	-146,717	22,725	-49,050	-12.94
Case 4 (organic, ext CBA)	395,162	-204,234	56,359	-461	-32

Table 7.10 shows the marginal impact on NPV from a 10% change in various revenues and costs. The table shows that revenues were the most important determinant of

profitability under both CBA analysis methods. This is understandable given that both projects had positive gross margins (and therefore higher values of revenues). This also shows the importance of improved marketing techniques, innovative distribution channels and timing of production that enable farm operators to receive higher prices for their produce. In organic production, this also reflects the importance of the price premium for the produce. The effect of the price premium is discussed in more detail in the subsequent paragraphs.

Table 7.10 also shows that a 10% change in sales revenues or operating costs cause larger effects on organic production than on conventional production under both analysis. This is rational since operating costs and revenues were initially higher for organic production. However, under the conventional analysis, both production methods became economically unfeasible (i.e. NPV below zero) when sales decreased by about 20.58% and 25.86% for conventional and organic methods, respectively. Similarly, both projects remained feasible as long as total operating costs did not increase by over 39.55% and 48.25% for the conventional and organic methods, respectively. Under the extended analysis, the organic system's NPV remained positive until revenues decreased by over 48.58% or when costs increased by over 92.05%, while the conventional system became infeasible when sales revenues decreased by about 18.02% or when costs were increased by about 34.63%. This shows that the economic feasibility of this organic system is more robust to changes in the values of revenues and operating costs under an extended analysis.

Under an extended analysis (cases 3 & 4), it is observed that changes in the values of employment benefits had the highest effects among the non-financial impacts on the profitability of the organic system (case 4). The conventional production system, on the other hand, was relatively more sensitive to changes in environmental costs (case 3). For example, a 103.57% increase in environmental costs will render the conventional production infeasible under the extended analysis. Changes to environmental costs had a lesser influence on organic profitability. This is justifiable since the organic system had much larger employment benefits and lower environmental costs than the conventional production system. This information can be concluded in another way by omitting the non-financial impacts from the analysis. Table 7.11 shows the effects on NPV when the non-financial impacts are omitted from the analysis for both conventional and organic productions.

Table 7.11: NPV From a 100% Change in non-Financial Variables

	NPV with Three Impacts	ExcludeTotal Employment Benefits (TEB)	Exclude Total Environmental Costs (TEC)	Exclude Total Health Costs (THC)
Case 3 (convent, ext CBA)	507,995	280,750	998,498	508,124
Case 4 (organic, ext CBA)	1,879,942	1,316,349	1,884,557	1,880,263

In this case, both production methods remain feasible albeit with significant changes to NPV.

The effect of changes in different variables on NPV can also be analysed at various discount rates to provide additional information about the robustness of project profitability. While the data are not presented here, it is expected that a 10% change in each impact decrease at increasing discount rates. Therefore, at different discount rates, some cases may become infeasible at different variations in the studied variables.

Another key variable that needs to be investigated is the effect of the organic price premium on project profitability. The price premium is often believed to be primarily the result of market effects, i.e. shortages of supply. While it is true that the demand for organic produce has been mainly bolstered by consumers' health concerns and their awareness to the negative impacts of agricultural pesticides, it may be incorrect to assume that price premium can be fully attributed to consumers' willingness to pay for such (non-market) services[170]. It may also be hard to find an exact relation between the two issues. Additionally, the demand for organic produce is expected to increase in the future as more consumers become aware of its comparative health effects.

Table 7.12 shows the effect of changes in price premium on the profitability of the organic production under the two CBA analysis systems.

[170] In this case, there will be no double counting of the benefits of organic method (i.e in price premium and in direct environmental and social benefits).

Table 7.12: NPV with Various Price Premiums under the Two CBA Analysis

	NPV	
Price Premium	Conventional CBA (Case 2)	Extended CBA (Case 4)
0%	-563,227	-78,923
4%	-509,298	0
10%	-459,933	84,953
20%	-356,639	248,830
30%	-253,345	412,706
40%	-150,051	576,582
41.36%	0	745,336
50%	-46,757	740,458
60%	56,537	904,334
70%	159,831	1,068,210
80%	263,125	1,232,087
90%	366,419	1,395,963
100%	469,713	1,559,839

The table shows that if organic produce was sold without the premium, then organic production would be unprofitable under the two analysis models. However, the extended analysis shows that a price premium of at least 4% was sufficient to render the project feasible, compared to a 41.36% under the conventional analysis. This shows how the premium becomes less important in determining the systems' profitability when other non-financial impacts (e.g. environmental and social) are accounted for.

7.4.4. Scenario Analysis

The analysis also investigated the results when more than one variable changed at the same time. In this case, four cases were considered: very pessimistic, pessimistic, optimistic and very optimistic. The changes to the costs and revenues in each case are listed in Table 7.13, and the results are shown in Table 7.14.

Table 7.13: Changes to Costs and Benefits for Various Cases

	Very pessimistic	Pessimistic	Optimistic	Very optimistic
All Costs*	+ 40%	+20%	-20%	-40%
All Benefits	-40%	-20%	+20%	+ 40%

* Except initial investment

Table 7.14: NPV for Different Scenarios under Various Cases

Change from Base Level (%)	Conventional Analysis		Extended Analysis	
	Conventional Production (Case 1)	Organic Production (Case 2)	Conventional Production (Case 3)	Organic Production (Case 4)
-40% (v. pessimistic)	-775,081	-923,703	-1,493,802	-745053
-20% (pessimistic)	-189,261	-126,111	-492,904	567,445
Normal	**396,559**	**671,480**	**507,995**	**1,879,942**
+20% (optimistic)	982,379	1,469,071	1,508,893	3,192,440
+40% (v. optimistic)	1,568,199	2,266,663	2,509,791	4,504,938

Table 7.14 shows that under the very pessimistic scenario, all cases are non-feasible. The profitability of the conventional production is more affected than the organic production when using the extended analysis, while organic production is more affected under the conventional analysis. Under a pessimistic scenario, only organic production is feasible under an extended analysis. If the results were optimistic and very optimistic, organic production produces better results under both analyses. This shows the importance of improved practices (which could reduce costs and increase revenues) in organic production on the firm's (marginal) profitability.

Additionally, the change in pessimism/optimism seems to have the largest effect in NPV in case four (1,312,498), followed by cases three (1,000,898), two (797,591) and one (585,820). This shows that the size of impact and rate of change is higher under the extended analysis in general, and within each analysis, the change is higher in organic production than in conventional production.

There may also be a large number of change combinations, whereby each parameter changes at different rates. These would have to be investigated on a case by case basis.

7.4.5. Weights

The system of weights helps to reflect the relative importance of each category of impacts to the region's population. The importance often reflects the seriousness of the situation in addition to the values of the community. The latter can usually be determined from survey techniques[171] or expert opinions (i.e. through a Delphi

[171] Questionnaires can help determine rating or ranking scales. Examples include Likert, Sematic Differential, Differential, Forced Ranking or Comparative Scales. More information about these scales can be found in Cooper and Schindler (2001). When weights are used to account for income distribution in the community, they are typically based on the social marginal utility of incomes

technique). Since it was difficult to assign exact weights for different impacts in this research, the analysis investigated the results when weights of various components are changed by a factor of 0.1. It should be noted that the values of weights for the various components can vary widely and their sum may not necessarily add to one[172]. Therefore, NPV values can be calculated for various weights combinations based on the situation under study. The marginal changes to NPV when the weight of one component is changed while keeping the weights of other components constant are listed in Table 7.15. The effect of changes to price premium is not considered here, since it was discussed in Table 7.6B.

Table 7.15: The Effect on NPV from a 0.1 Upward Change in the Weight of One Variable

	A 0.1 upward change in the weight of health costs (with all other weights constant)	A 0.1 upward change in the weight of employment benefits (with all other weights constant)	A 0.1 upward change in the weight of environmental costs (with all other weights constant)	A 0.1 upward change in the weight of net economic production figures (with all other weights constant)
Conventional production	**-13**	**22,725**	**-49,051**	**135,227**
Organic production	**-32**	**56,360**	**-462**	**190,927**

The above table shows that financial effects have the largest effect on NPV in both production methods. However, under conventional production, a change in the weight of environmental costs has the second largest effect on NPV. Therefore, concerns for the environment in the society will make a significant impact on the results of project analysis. Similarly, a change in the weight of employment benefits has the second largest effect on project profitability in organic production.

(Dreze, 1998). In this case, benefits and costs accruing to various households could be weighted by their marginal social utility β_i, which is given by $\beta_i = Y_i^{\wedge -\rho}$ with Y_i equal to the individual i's level of utility measured in some monetary measures, and the parameter ρ is the coefficient of aversion to inequality, or the elasticity of the marginal social utility of Y_i, which captures the extent to which one wants to put higher values on monetary gains accruing to various households. Another weighting scheme suggested by Ray (1984) is to use a factor based on changes in consumption levels of a group (or incomes) compared to the national consumption levels, adjusted by the elasticity of marginal utility of income.

172 In this case, NPV will be overstated but the values of NPV can then be used for comparison at different weights.

7.5. Interpretation of Results

The results of analysis are summarized in Table 7.16, which shows the effects of incorporating non-financial impacts, manipulating the discount rate and the inclusion of weights for both the organic and conventional production methods.

Table 7.16: Summary of Results for the Two Production Methods

	NPV from Standard CBA	Marginal NPV from Employment impacts	Marginal NPV from Environmental impacts	Marginal NPV from Health impacts	NPV from Extended CBA
1- Section 1					
Organic production (@8%) **1**	671,480	385,111	-2,911	-219	1,053,460
Organic production (@4%) **2**	1,321,285	563,593	-4,615	-321	1,879,942
Effect of lower discount rate **(2-1)**	649,805	178,482	-1,704	-102	826,482
Effect when env. & social weights=1.1 @ 4% **4**	1,321,285	619,952	-5,076	-353	1,935,808
Net effect of weights **(4-2)**	0	56,359	-461	-32	55,865
2- Section 2					
Organic production without premium (@8%) **5**	-563,227	385,111	-2,911	-219	-181,246
Organic production without premium (@4%) **6**	-637,580	563,593	-4,615	-321	-78,923
Effect of lower discount rate **(6-5)**	-74,353	178,482	-1,704	-102	102,323
Effect when env. & social weights=1.1 @ 4% **8**	-637,580	619,952	-5,076	-353	-23,057
Net effect of weights **(8-6)**	0	56,359	-461	-32	55,866
3- Section 3					
Conventional production (@8%) **10**	396,559	155,280	-325,882	-88	225,869
Conventional production (@4%) **11**	771,382	227,245	-490,503	-129	507,995
Effect of lower discount rate **(11-10)**	374,823	71,965	-164,621	-41	282,126
Effect when env. & social weights=1.1 @ 4% **13**	771,382	249,970	-539,553	-142	481,656
Net effect of weights **(13-11)**	0	22,725	-49,050	-13	-26,338

The above table shows the marginal effect on NPV from incorporating employment, environmental and health impacts into the analysis. Of the three non-financial impacts, employment impacts have the largest marginal effect on NPV in organic production ($385,111), compared to environmental impacts in conventional production (- $325,882). Adding the effects of the three impacts to the NPV values derived under the standard CBA analysis have changed NPV by 56.88% and -43% (at 8% discount rate) for organic and conventional productions, respectively. Additionally, changing the discount rate from 8% to 4% seems to cause a significant change in NPV in both the organic and conventional productions. In this case, NPV values under the extended analysis have increased by $826,482 and $282,126 for the organic and conventional productions, respectively. In both cases, the effect of the discount rate was larger than the effect of incorporating non-financial impacts.

Summing the effects of incorporating non-financial impacts and changing the discount rate show that NPV from the standard analysis has significantly increased from $671,480 to $1,879,94, which represents a difference of $1,208,462 or an increase of 180% in organic production. Similarly, there was a change in NPV for conventional production, but it was smaller, i.e. $111,436 or 28.1%.

The introduction of weights also makes a difference in the values of NPV under the extended analysis. For example, a 10% increase in the weights of non-financial impacts has changed NPV by $55,865 and -$26,338 in organic and conventional productions, respectively.

Another important observation revealed by the results was the effect of the price premium received by organic produce on the profitability of the organic production system. If the premium was removed, then incorporating the studied non-financial impacts as well as the 4% reduction in the discount rate and the incorporation of an additional 10% weight on the environmental and social impacts, were not sufficient to turn NPV to positive values although they have helped to increase it significantly from -$563,227 to -$23,057. However, the usage of lower discount rates or larger weights could bring NPV into positive figures, equivalent to the effect of a price premium of 4%, as shown in the sensitivity analysis.

The above results clearly indicate that the extended CBA analysis has shown significantly different results than the standard analysis. This is important as it will show analysts, who are usually guided by the maximization of a firm's wealth as the sole decision criterion, the importance of looking beyond the direct financial returns when dealing with projects that involve environmental and social aspects. In this research, when the extended analysis was used, the profitability of the two production methods were significantly different than the results generated under the conventional (CBA) analysis, and the effects of the environmental and social impacts of the studied production systems were better represented. A different methodology did show significantly different results.

Additionally, the extended analysis could help to support some sustainable development objectives, namely, the conservation of environmental resources and positive contribution to social welfare by serving as an improved decision-making tool that shows a more comprehensive picture of the costs and benefits of the production systems, especially the benefits of the organic farming system discussed in this research. In this case, the extended analysis has shown that the net social benefits of the organic system exceeded its net private benefits, and this may form a basis for more supportive governmental policies.

A conclusion about the overall improved effects of organic systems in general, can not be reached here due to the scope limitations of this research. However, the extended analysis presented in this research may be helpful in supporting the fact that some organic systems, when assessed in a more comprehensive manner, offer improved economic benefits over conventional production systems.

The extended analysis has shown that the economic profitability of the organic system, discussed in this research, was more robust over wide changes in related factors such as discount rates, price premiums and other non-financial impacts than under the standard CBA analysis. The above result supports the widely held view of many organic farmers about the stability of organic systems as compared to alternatives. Additionally, this conclusion could prove to be useful to hesitant farmers embarking on conversion[173] to organic methods as well as policy makers when formulating relevant support programs.

---

[173] While many farmers are concerned for the environment and for their society, literature (e.g. Midmore *et al.*, 2001) has shown that these issues were often not sufficiently convincing for conversion to many farmers. Farmers also worry about availability of financing or liquidity to support reductions in income in the initial transition changes, availability of markets, fluctuating consumer demand, , governmental support and subsidy programs etc. Organic farmers also worry about major pest infestation pr extreme weather conditions, which are usually harder to counter in organic production.

CHAPTER 8

DISCUSSION & CONCLUSIONS

8.1. Introduction

This chapter provides a brief summary of the work done in this research. It also discusses the results and outlines some of the main conclusions. Additionally, It presents some recommendations for future research.

8.2. Summary

This research has attempted to present some extensions to the cost-benefit analysis, to serve as an improved analytical and planning tool that could better reflect and integrate some of the values identified in the sustainable development paradigm. The extended analysis was then operationalized to analyze certain organic farming practices as an example of sustainability within farm operations.

The extended approach involved three main points: 1) to include, in addition to the direct financial costs and benefits, relevant external environmental and social implications of the project, which were estimated using selected physical and monetary evaluation techniques; 2) to use an adjusted discount rate which could be argued to be more sensitive to social and environmental considerations; and 3) to introduce a system of weights that can better reflect the community's concerns about environmental and social values in general and the prevailing state of damage to the environment, specifically.

A sustainability criterion was indirectly embedded in the analysis by incorporating corrective costs into the monetary evaluation techniques, i.e. costs to correct for some of the environmental damages observed. This latter point was tackled from a weak sustainability perspective, which accepted the substitutability between natural and man-made resources.

The data used was derived from a combination of primary and secondary sources, namely, direct personal interviews with farm operators and experts in addition to data published by governmental sources in Quebec.

There were some difficulties in the quantification of all relevant impacts and in the selection of appropriate valuation techniques. Inevitably some subjective value judgements were used, supported by objective reasoning wherever possible.

The analysis was done for four cases; organic and conventional farm production under standard and extended analyses. A sensitivity analysis was then conducted to account for risks and uncertainties that may arise in the market and to better deal with the complex and intertwined variables of the ecosystem and the environment.

Results showed that the extended analysis model, which integrated various components, and accounted for previously omitted externalities, has better reflected the economic and societal benefits of the organic production system than the standard analysis model. This may make it a better decision aid tool and a useful approach for projects that have environmental components in general. An extensive sensitivity analysis has helped to increase confidence in the results and provides valuable information for the analyst.

A series of conclusions can be derived from this research. These are presented in the following section.

8.3. Discussion and Conclusions

This section presents a discussion of the results as well as some major conclusions from this research. These are listed in points as follows.

i. By broadening the objectives of the CBA analysis beyond economic efficiency and widening the framework of analysis to include some of the relevant non-marketed environmental and social impacts, and by considering the distributional components, either through the introduction of weights or by the adjustment of the discount rate, the extended CBA, could prove to be a better decision tool for incorporating, accounting for and integrating some of the objectives, values and components embedded in the spirit of sustainable development. These include sustainable economic growth that considers conservation of and reduced damage to the natural resource capital[174] on which production partially depends, equity

[174] Sustainable rates of resource use.

impacts (inter and intra-generational tradeoffs)[175] and social concerns including the provision of increased rural employment opportunities and the preservation of rural communities. This would eventually lead to improved social decisions and to systems with greater environmental sustainability.

ii. By using an extended CBA for the analysis of sustainable production practices, such as the specific organic production model discussed in this research, the extended model has helped to show that this production model offers economic gains to the society in excess of its financial private benefits, and that these net economic benefits are larger than those of the comparative conventional production model; an issue which was not adequately observed under the standard CBA analysis. Therefore, the extended analysis is likely better to reflect various sustainability objectives within farming operations, and could allow better comparison of various farming systems in terms of their relative sustainability, even when the indicators/measures of sustainability are expressed in (aggregated) monetary terms[176], as in this case. Part of these gains are manifested by reduced negative environmental impacts and improved patterns of resource allocation and usage, since organic production is potentially less damaging to soil and water resources, less energy intensive and depends less on non-renewable resources (Lampkin, 1990; Stolze *et al.*, 2000), which is likely to result in improved benefits to current and future generations. Generally speaking, improved patterns of resource allocation could potentially result in improved patterns of income distribution since environment and income are often supposed to be strongly linked[177]. In addition, this organic production model has shown a potential to increase rural employment opportunities. All of these positive points, when applied on a larger scale, may lead to improved equity among different sectors of the community and between generations as well as improved patterns of resource

[175] The issue of inter-generational equity or future generations' rights is also considered under an extended analysis by accounting for the environmental impacts that may affect their welfare, i.e. the benefits and costs of the economic growth have to be clearly accounted for and fairly distributed to both current and future generations.

[176] It is important in other cases, to identify the sustainability objectives and its relevant criteria and indicators as well as objective means to sum the various performance measures (Lampkin, 1998).

[177] The philosophy of sustainable development considers that environmental quality and economic progress to be complementary objectives. Therefore, a changing policy toward the management of natural resources will affect economic development and progress. This is especially true in developing countries.

utilization. These findings enforce the results achieved by several scientists (Midmore, 1994; Lampkin and Padel, 1994; Jansen, 2000; Offermann and Nieberg, 2000 and Stolze *et al.*, 2000) about the positive benefits and improved economic performance of sustainable production systems in general, and organic in particular.

The preceding two points would support the hypothesis of this research study and its objectives, stated in Chapter One.

iii. The above arguments may support farmers' conversion, and may justify policy interventions, especially those that aim for environmental enhancements (and resource conservation), improved social well-being, and may help to make a case for increased support for farmers purusing sustainable production models.

iv. The research has stressed the importance of realizing the synergy between the many issues/objectives (i.e. social, environmental and economic etc.) involved in sustainable economic development in general, and project evaluation in particular (Hufschmidt *et al.*, 1983). Environmentally-related projects are multi-dimensional and multi-disciplinary in nature, and sustainability requires the integration of all related impacts in policy making (Soderbaum, 1987, Aldy, 1998; Midmore and Whittaker, 2000; Regmi and Weber, 2001). This issue is of particular importance to (farmers and policy makers in) the province of Quebec, which will benefit from more research on the economics of integrated impacts of organic farming in the province and from further comparative studies (and methods) between the two production systems, especially if there is improved research into the possible negative externalities caused by conventional agriculture (e.g. Pimental *et al.*, 1992; Bailey *et al.*, 1999 and Pretty *et al.*, 2000). Furthermore, The need for the development and application of integrative evaluation tools, to assess the relative sustainability of various systems in general (e.g. Lampkin, 1998; Bouchart *et al.*, 1998; Pretty *et al.*, 2000; Stolze *et al.*, 2000 and Simonovic, 2001), and the various impacts of sustainable agriculture in particular, is growing as the adoption of sustainable farming systems has widely increased in the last decade (Andreoli and Tellarini, 2000). So it is hoped that improved valuation techniques/decision support tools, that involve several objectives, of economic, social and environmental nature, would add to the efforts made by other scientists such as

Bockstaller *et al.* (1997), Bailey *et al.* (1999), Cobb *et al.* (1999), and Girardin *et al.* (2000). This could eventually lead to improved effectiveness in the management of natural resources, as well as in the development of related policies and plans in pursuit of sustainable development objectives.

v. This research has used market-based techniques to examine the costs and benefits of achieving sustainability objectives within farm operations, thus enforcing the conviction of the positive role of economics in general, and the neo-classical paradigm in particular, in the debate on sustainable development (e.g. comments of Henderson, 1981; Ekins, 1986). Central to this argument, is the continuous role of the market system (equilibrium and price signals) in optimal welfare distribution, efficient allocation of resources, and the ability of the (current) economic tools to correct for inefficiencies that may have resulted from externalities caused by the omission of environmental costs associated with projects[178]. Feeding corrections back into the (market) system will help reinforce confidence in it. This can be seen in this research in the usage of market-based techniques to place monetary values on related environmental and social impacts[179]. Therefore the needed modifications were done from within a market framework, by re-visiting the underlying, standard economic assumptions and performing some adjustments (as suggested by Randall, 1987; Tietenberg, 1992; Midmore and Whittaker, 2000). It should be noted that some criticisms of CBA may be justified when it relies on non-market valuation methods (e.g. TCM, CVM, etc). These criticisms focus on the CBA assumptions of anthropocentric nature of economic values (Hanley and Spash, 1993), its reductionist nature and atomistic approach (Norgaard, 1989), and utilitarian values. Therefore a thorough justification and a clear explanation of the assumptions used and limitations may be needed when these valuation techniques are used.

vi. The methodology used has helped to reach a single cumulative figure (monetary value for the relevant impacts), which can be used as an indicator for easier comparison and ranking of projects and more specifically, for the comparison between various production methods. It should be noted that the issue of

[178] Such externalities can also be caused by ill-defined or unclear property rights.

[179] The domain of environmental economics is continuously being developed to better account for environmental externalities within the neoclassical economic paradigm.

determining a single measure/indicator or index for sustainability has so far been a difficult and a contentious issue[180] (Lampkin, 1998; IISD, 1999). The usage of the NPV figure determined by the extended CBA, offers a practical solution since monetary values are the most widely used (and understood) indicators, and its usage, may consequently lead to better decision-making. However, as some researchers may debate the economic values placed on certain environmental and social consequences, it should be noted that the figures determined in this research were not the ultimate (or even the main) aim of this work, but it is primarily the exercise with its alternative way of thinking that is hoped to add intellectual value. The estimated figures have served to provide an indication of how important these variables were, and the difference they would make to the analysis when they were included. Therefore the figures are to be considered as providing indications of possible orders of magnitud that offer better information and guidance. Generally speaking, the lack of complete understanding of the ecological relationships between different variables, and the absence of markets for many of the involved impacts, often make it difficult to determine accurate figures in such cases, and consequently prevent a full audit/comparison of the ecological merits of organic practices. The value added from this research is believed to have been an attempt to provide a "road map" rather than a complete solution, which would enrich the intellectual debate about suitable support policies for sustainable agriculture.

vii. The suggestions made in this research for extending the CBA are non-unique but may not be universally suitable. Applying CBA to environmental management is partly an art, and its application requires good and sometimes subjective judgement. The extensions suggested here are believed to be relevant to the problem under discussion and the prevailing conditions. These may also change in the future as the concept of sustainability continues to evolve further.

[180] The development of sustainable indicators is still the subject of ongoing research by many governmental and non-governmental agencies. Some of these agencies include Environment Canada (Canadian Environmental Advisory Council, State of Environment Reporting), National and Provincial Round Table on Environment and Economy, Canadian Council of Ministers of the Environment, Canadian International Institute for Sustainable Development, Agriculture Canada, OECD, United Nations Development Program's Department for Policy Coordination and Sustainable Development (UNDPCSD), Institute for Perspective Technological Studies (EU), Institute of Arable Crops Research (UK), etc.

viii. The extended model has better shown the economic benefits from the studied sustainable production system. It is hoped that when economic benefits become more visible in general, that this may lead to a stronger case for supportive agricultural policies and economic incentives to promote sustainable development within agriculture in general, and the adoption of sustainable production practices[181], including organic methods, in particular[182] for different time frames[183]. This repondss to the comments of Lockeretz (1989) and Midmore and Whittaker (2000) on the necessity to effectively transmit all information on changes in relevant components in a system to provide a better opportunity for adaptation.

Examples of such policies, subsidies and incentives[184], could include the removal of certain price supports on conventional produce, reduction of import duties on organic inputs, introduction of natural input subsidies, increased pollution taxesdirect and credit subsidies, etc. The suggested subsidies[185] can be met from taxes imposed on certain environmentally-damaging practices or from a levy on (production, import or sales of conventional) agricultural chemicals and therefore, is not expected to add financial burdens to tax-payers. Additionally, the local government and credit agencies could create certain direct incentives to support the conversion to more sustainable farming, such as increased credit availability (or even credit gurantees), marketing support, increased education (and training) to both the farmers and the general public. Such programs could prove to be equally useful in promoting a greater adoption of environment-friendly production systems. Supporting programs may need to be complemented by other institutional arrangements, such as a redefinition of property rights, for example, for clean water. Therefore using improved assessment tools, such as this extended CBA, is only one step in designing policies for sustainable development. Another important issue in supporting sustainable development objectives, especially when

---

[181] Or at least to promote policies that are less harmful to environment.

[182] It should be noted that on-farm decisions about land use are made by the farmers in light of their own objectives, production possibilities and constraints, and not by government support policies.

[183] That is, short, medium and ling time frames. For organic farming, support is particularly needed during the early stages of conversion.

[184] These may include a training subsidy, low-cost extension support, low tariffs on natural imports, free seminars and reduced land tax.

[185] The subsidies on organic production should not exceed the difference between the net social benefits and the net private benefits derived from organic production.

there are risks of irreversible damage to the environment, is to insure sufficient backing by administrative and legal controls[186]. Therefore, individuals, including analysts and public decision-makers have to accommodate environmentally sustainable objectives and recommend economic activities across various economic sectors that are compatible with these objectives[187].

ix. A sustainability constraint[188] may sometimes need to be embedded in the regular decision-making techniques for projects with critical environmental impacts. In other words, a project with positive NPV should not be implemented if the project results in substantially negative environmental impacts (that are below the system's carrying capacity)[189] or which cause major negative social consequences. This will lead tothe analysis being concerned withprocess and not just results (Schulze and Howe, 1985). However, the sustainability constraints should be based on well-defined ecological and social criteria and standards (in addition to political judgement), including well defined parameters, threshold levels, acceptable levels of risk, relevant definition of intra and inter-generational equity and acceptable tradeoffs between various forms of capital and compensating projects (Pearce *et al.*, 1988; van Pelt, 1993; Neumayer, 1999). The sustainability constraint will also contribute to the ranking of projects, and can be used to reject economically profitable projects if it does not achieve or meet perceived requirements for sustainability, which cannot be traded for money. However, for this to work, it also requires policy interventions (e.g. regulations and standards etc.) along with sufficient monitoring and enforcement measures. While in reality, the operationalisation of the sustainability objective is a difficult process due to the many complications and uncertainties involved (Pearce, 1991; Munasinghe and Lutz, 1993; von Amsberg, 1993), it is mentioned here to stress the fact that decision-makers should base their conclusions on both qualitative and quantitative impacts and assessments.

[186] This may also include continuous monitoring and enforcement of laws.

[187] Additionally, other objectives that are culturally and politically important may sometimes need to be accounted for.

[188] Based on either weak or strong sustainability criteria.

[189] Even under an extended analysis, where impacts causing irreversible environmental damage are highly priced, some ecologists have suggested that such projects be prohibited regardless of a positive sum for total net benefits.

x. The extended CBA discussed in this research may make the technique an improved decision-tool that better accounts for the values of sustainable development, but it is still far from being perfect or complete. The technique still embeds utilitarian values, but the ensuing negative impacts (if any) are expected to be less with the introduction of distributional weights, which will socially adjust the values of relevant costs and benefits, and distributional effects. Additionally, the reliance on economic efficiency is still a key issue, however, attention is now directed toward achieving social efficiency with multiple objectives and not simply private efficiency (as a sole objective). The extended analysis still helps to show whether a potential Pareto-improvement exists, which is by itself an important issue even when the compensation is potential. In this case, damage to the environment is expected to be less when it is accounted for. Compensation could also be achieved through other projects or related policies.

Widening the framework of analysis by accounting for externalities will help reduce the bias toward projects that omitted them, and allow market prices to better reflect the costs and benefits to society (Kirkpatrick and Lee, 1997). It is true that the values placed on some of the studied environmental and social impacts may be debatable, but this issue is often contentious from various viewpoints (e.g. scientific, ethical and social), regardless of the amount of effort made. Still, the marginal benefit to the analysis from accounting for these impacts is higher than from excluding them, especially when the limitations to the used valuation techniques are acknowledged.

The study has only estimated the significant impacts that can be valued with more certainty and with reasonable assumptions given the available data sets. In doing so, the analysis may have missed several important aspects of both production methods. A more comprehensive accounting of impacts is often hindered by technical difficulties (Pretty *et al.*, 2000), uncertainties or by lack of understanding of the complex ecological relationships among variables, which force the analyst to restrict the scope of analysis. However, the selection of impacts in the analysis should be primarily based on their relative importance, even when difficulties exist, as long as the assumptions used in the valuation are thoroughly explained and deficiencies mentioned. Accounting for other components of the Total Economic

Value in the future, as advocated by many economists (e.g. Dixon, 1994; Markandya, 1998; Turner *et al.*, 1993), such as indirect use, option, bequest and existence values, for other attributes of a natural resource, when quantification and valuation techniques permit a better capture of such issues, is expected to further demonstrate the usefulness of an extended CBA approach, and in this case, better reflect the value of the (negative and positive) externalities associated with both production methods.

The extended technique still relied on discounting despite its criticisms (Markandya and Pearce, 1991; Norgaard, 1991), but it used a rate that is lower than the market-generated rate, which some consider to be more socially and ethically favourable[190]. It is believed that this may result in a more equitable distribution of resource benefits and costs among generations. Methods to determine optimal values or functions for the discount rates to better reflect sustainable development are still unclear / undecisive.

CBA is expected to remain a vital decision tool and a widely solicited technique by policy makers, who have to consider various social and economic objectives in their policies based on their definition of a social welfare function, and political agenda among other issues. However, it is hoped that a revised tool, albeit with the above non-perfect modifications, will be more informative and could offer better guidance[191] to help reach better decisions in environmental accounting, especially for projects with environmental impacts or those promoting sustainable development.

xi. While there exist other decision techniques that can be useful in environmental economics such as Cost-Effectiveness Analysis (CEA), Environmental Impact Assessment (EIA) and Multi-Criteria Analysis (MCA)[192], each of these techniques has its own advantages or disadvantages over CBA, depending on the situation under study. Some of these techniques (e.g. MCA, EIA) may even facilitate the comparison of projects using qualitative data if the quantitative data was not

[190] As it helps protect the interests of future generations.
[191] Analysts should be aware of the limitations of any technique they use.
[192] EIA mainly involves the identification and physical quantification of the environmental consequences of projects. CEA looks at the cheapest way to reach the objects, i.e. consider costs but not benefits.

available, i.e. unlike CBA, the techniques may not require the full monetarisation of effects).

This research can not offer any conclusive comparison about the relative merits/suitability of different methods. However, an extended CBA analysis, which accounts for several objectives will partially capture the main advantage of the MCA (if these impacts can be properly monetized), although the extended CBA still has not offered a decisively unique method for the weighting and scoring of various objectives, an issue which is still not objectively resolved under the MCA technique anyway (Stirling, 1997 and Lampkin, 1998). This still offers an improvement over the usage of a standard CBA, whose values are usually used for the efficiency objective within a MCA[193] (Hanley and Spash, 1993). Additionally, in accounting for environmental impacts, the extended CBA provides some of the additional information supplied by the EIA[194] even when CBA reports the impacts in monetary terms. (However, unlike EIA, the extended CBA may be incapable of incorporating many of the (non-monetized) environmental impacts associated with agricultural practices).

In all cases, combining information provided by several decision techniques (including the CBA), either separately or within an MCA framework, is likely to improve decision-making[195], and should often be the case for critical projects.

xii. While this research has considered a revised economic instrument to support sustainable development, it is hoped that the results of this research can assist decision-makers to make better decisions, and move policy makers to re-set their priorities toward operationalising sustainable development. Furthermore, it is hoped that this study may lead to further studies and contribute to the current intellectual debate.

---

[193] An MCA can be used to assess the relative sustainability of different systems or farming methods using various sustainability criteria and the results of the standard CBA for the financial criteria (e.g. Lampkin, 1998; Bouchart *et al.*, 1998; Stolze *et al.*, 2000). This requires appropriate definition of the sustainbaility criteria and the indicators for measurement.

[194] EIA also uses certain scoring systems to sum up various categories of environmental impacts and to permit comparison across projects. However, these scoring technqiues are often controversial (Hanley and Spash, 1993). It should be noted that EIA, like CEA, only considers the cost side of a project.

8.4. Avenues for Further Research

i. It would be desirable to include additional impacts such as those on wildlife, fish, recreation and other existence values, etc. in the analysis when more data becomes available. Accounting for these issues is expected to show even further the benefits of using an extended CBA model.

ii. Methods could be explored to further incorporate risk and uncertainty in the analysis and to evaluate ways that can best account for potential irreversible impacts.

iii. The analysis could be extended to include a differential treatment of future costs and benefits[196] and to see whether this can add value for the decision-maker. This can be done from at least three perspectives: 1) by using a non-constant discount rate, which could emphasize inter-generational choices differently; 2) applying the Krutilla-Fisher theory, which assumed that benefits would decrease and costs increase over time, therefore reflecting changing market situations, including scarcity[197]; and 3) investigating how various weighting/scoring methods can be used to reflect various sustainability criteria, especially equity issues and social welfare within and among generations.

iv. The results of this analysis could be compared with the results generated using other decision techniques such as Environmental Impact Analysis (EIA), Multi-Criteria Analysis (MCA), input-output modeling[198] etc, and ways explored to determine the optimal use of the above-mentioned techniques in conjunction with the extended CBA. Additionally, it may be beneficial to determine the extent to which these other techniques are capable of reflecting the relative sustainbility[199] of various farming systems.

v. The overall impacts of a wider adoption of organic production conversion across the whole province could be investigated. In addition to the obvious environmental

---

[195] These techniques can be used as complementary appraisal tools.

[196] Future costs and benefits are assumed to be (continuously) variable in real values over time.

[197] The application of this theory depends on finding appropriate values for the rates of change in costs and benefits over time.

[198] The I-O modeling can be extended to account for external flows such as pollution and natural resources utilization.

and social effects, macro-economic impacts, such as the effect on prices of inputs and outputs, employment, subsidies, trade etc, could be analyzed.

vi. It would be desirable to examine how current and future technological changes and rapid advances in scientific knowledge, especially in the field of genetic engineering, will impact on the definition and paradigms embedded in sustainable development in general and environmental values in particular, and how this may reflect on project evaluation. Additionally, it would also be desirable to examine how or whether the impact of globalization, with its implications for industry structures, consumer preferences, prices, standards for food safety etc, could constitute additional challenges to rigid governmental policies and farmers' managerial abilities, especially when these issues threaten the economic and social security of many farmers.

vii. The effects of factors such as increased environmental awareness, relevant education and conservation oriented ethical campaigns could be considered in addition to the effect of support and subsidy policies on the adoption of sustainable practices in particular and in promoting sustainable development in general. In this manner, factors that may influence consumer values and attitudes could be examined.

---

[199] This latter issue often depends on appropriate definition of sustainbaility objectives, criteria and indicators for measurement.

APPENDIX A

PRODUCTION PRACTICES AT THE TYPICAL FARM

A.1. Introduction

This section provides information about the typical farm. This includes a detailed description of the assumptions about the biophysical characteristics, methods of production and environmental impacts as well as a discussion of other assumptions made. This information is derived from personal field visits to the region and interviews with organic farmers in addition to consultations with extension agents and agricultural experts[191] between 1993 and 2001.

These consultations also contributed to the understanding of the common practices followed in vegetable farms under typical conditions in the province of Quebec.

A.2. Description & Characteristics of the Typical Vegetable Farm

The farm is located in the Monteregie region (administrative region No.16), where most vegetable production occurs in the province. Monteregie lies in the St. Lawrence lowlands where the main agricultural activity in the province occurs. As with the case of most farms in the region, the typical farm is assumed to be adjacent to the St. Lawrence River.

The total area of the farm is 17 hectares[192] (ha), of which 16 hectares are used for planting. This area is comparable to the average size of conventional vegetable and potato farms in the province[193]. The farm includes a residential house for the owner/operator and his family as well as a storage barn and a plastic-covered greenhouse for growing seedlings. The predominant soil type is sandy loam[194] with a topsoil depth ranging from 23 to 30.5 cm (9-12 inches). The land has a slope that ranges from 4 to 9%. Water for irrigation is supplied from a well located on the farm and from on-farm (water) collection ponds.

---

[191] Some of these interviewed include Russel Pockok, Aline Savary, Frank Pellerand, Caroline Morin, Pierre Sauriol and Denis La France.

[192] A hectare is 10,000 square meters.

[193] The provincial average sizes for conventional vegetable and potato farms are 14.9 and 21.8 hectares, respectively (MAPAQ, 1998). Organic farms are usually of smaller sizes.

[194] The soil composition is 60-80% sand, 20-40% silt and 2-3% clay.

The typical farm is assumed to be in vegetable production for several years. In this research, two production scenarios are evaluated for the same farm: in the first, the farm is producing vegetables conventionally, while the second, captures the organic production, assumed to have started in 1995. The conversion (process) to organic requires three years, to allow synthetic chemical residues to leach out of the soil[195]. During the transition period (1995-1997), the farm operator continued to grow vegetables using organic methods but the crop was sold as conventional produce.

While there are a variety of vegetable crops that can be produced conventinally in Quebec, there seem to be less choice for farm operators when it comes to organic vegetables. This depends on market demand, crop marketability and prices, crop rotation requirements and compatibility of machinery. The most common organic field crops produced in the province were cabbage, lettuce, carrots and beans[196], assumed to be produced on equal plots of land. Therefore the two production scenarios will focus on these crops.

General information about these crops is shown in Table A1. The farm has no livestock animals.

Table A1: General Information about the Studied Crops

	Beans	**Cabbage**	**Carrots**	**Lettuce**
Start in	Field	Greenhouse	Field	Greenhouse
Start from	Seeds	Seeds	Seeds	Seeds
Growing season (days, early-late varieties)	55-80	95-135	58–100	65-80
Days in green house	0	30-35	0	25-28
Days in field (early, late varieties)	55-80	65 -100	58-100	40-62
Nutrient requirements	Nutrient Builder	High	Low	Medium
Nitrogen requirements (kg/ha)	45	135	80	80
	Beans	**Cabbage**	**Carrots**	**Lettuce**
Phosphorus requirements (kg/ha)	70	125	40	50
Potassium requirements (kg/ha)	65	170	230	110
Pest susceptibility	Low	High	Medium	Low

195 This is a requirement by organic certification agencies.

196 Beans are used as soil nutrient builder due to its nitrogen-fixing ability in the roots.

Plant Spacing (inter-row * intra row in meters)	0.75*0.05	0.75 * 0.35	0.75*0.1	0.75*0.25
Final no. of plants per hectare	266,666	38,095	133,333	53,333
Yield unit	Kg	Kg	Kg	Head
Avg. conventional yield (units/ha)	7,700	39,044	31,780	43,200
Avg. organic yield (units/ha), % of conventional	65-85%	65-85%	65-85%	65-85%

A.3. Production Season

The production season for field crops starts from late April to early May after the last frost, which usually occurs in early May, and extends to the end of October. A cover crop is often planted after harvesting to protect the soil during the winter season.

A.4. Practices and Main Assumptions for the Organic Production

There exists many ways to produce vegetables organically depending on factors such as farmers' experience, soil characteristics, available machinery, restrictions imposed by the certification agency and financial resources. To insure that this farm is as close as possible to a typical vegetable farm in Quebec, the farm production practices were designed in consultation with agronomic consultants to insure that they match common practices in the province and that standard machinery is used. This was important since the information is used to estimate representative or typical organic production budgets. These are discussed in detail in the following sections.

A.4.1. Field Preparation

Field preparation takes place mainly in the spring before the season starts but is sometimes started in the fall of the previous year after the harvest, depending on the crops produced and the rotation plan. When a cover /green manure crop is planted in the fall, it would be ploughed in the spring, at a depth of 17.5 to 20 cm (7 to 8 inches) deep, to break and loosen the soil and bury plant residues around two to three weeks before the expected planting date, as field conditions permit. In the spring (April), the field is usually disk harrowed or grubbed to break the lumps. This is followed by the preparation of soil beds (150 cm wide in this farm, with two rows), using a rotary tiller. For crops produced in rows instead of beds (i.e. cabbage), the field is harrowed.

Compost, if fully decomposed[197] is applied in the spring at around one and a quarter cm (half inch) thickness and is disked into the soil. It is a rich source of organic matter that helps to improve soil physical properties (drainage, aeration and water holding capacity) and is considered to be the main (and natural) source of nutrients for organic production. The farm operators use a total of 192 tons on the 16 hectares per year. A Phosphorus fertilizer such as rock phosphate[198] is usually added in the fall every few years due to its slow decomposition. A list of operations followed as well as the equipment used to prepare the plots for various crops is shown in Table A2.

Table A2: Field Preparation for Various Crops

	Plot 1 Cabbage	Plot 2 Carrots	Plot 3 Beans	Plot 4 Lettuce	Plot 5 Green Manure
Soil preparation					
Chisel 8 tines, tractor mounted, 2 m wide	2	1	1	1	
Chisel 8 tines, tractor mounted, 2 m wide			1 (47% of plot)	1 (31% of plot)	
Cultivator, heavy tine, 10 feet	1 (94% of plot)	2	1		
Cultivator, vertical axis rotary (Roterra), 1.5 m wide	1 (94% of plot)	3		1	
Disk, heavy disk, 8 feet	1	1	1	2	
Plow, 2-3 shares	3 (6% of plot)			1	
Plow, 2-3 shares	2 (94% of plot)				
Subsoiler, 1 m wide, tailor made					
Compost preparation & spreading					
Spreader, manure & compost, 3-4 tons					
40 tons/ha	1				
20 tons/ha			1		
Manure 20 tons/ha	1			1	
Turner, compost, with motor	3		3		

A.4.2. Seedling Preparation and Planting

All the studied vegetables are started from seeds. Cabbage and lettuce seeds are started in the greenhouse, and are then transplanted into the field. Beans and carrots are planted directly in the field in the spring. In the greenhouse, organic (untreated)

[197] Compost can sometimes be applied in the fall, instead of spring, if not fully decomposed.

seeds are seeded in plug trays[199] (usually 128 plugs in 28x54 cm trays), often with homemade pneumatic seeder, filled with a nutrient-rich potting media starting from late March till early May (depending on the field planting date and days for germination). Few weeks later, the seedlings are transplanted into the field using a mechanical transplanter with plant holders starting from mid April to mid May depending on the seedlings' tolerance to cold weather and soil temperature. Crops that are seeded directly into the field, such as beans and carrots are sown with a seeder/planter. Farmers usually do succession planting, that is, they divide the area they want to plant into different plots, and plant each plot at different times usually with a week to ten days difference. This is made to reduce the risk of weather changes, pest infestation, and fluctuations in market demand and prices. For that, they usually use different crop varieties that are more frost resistant. In this research, it is assumed that all the crops are planted at the same time. This will not affect the total costs although succession planting may require little more labor time (mainly for more frequent machinery preparation).

When a soil cover is needed to protect early crops from frost, the farm operator uses fleece. Organic farmers also use plastic mulch (which is normally accepted by certification agencies) and/or straw.

A.4.3. Fertilization Plan

Farmers in Quebec usually plan their fertilizer requirements based on the recommendations found in the Fertilization Guide published by the "Council of Vegetable Production in Quebec[200]" (Table A-1). These consisted of three main minerals (nitrogen, phosphorus and potassium) in addition to trace minerals (e.g. magnesium and calcium). The latter are usually required in lesser amounts. The fertilizers and the application rates generally depend on factors such as soil type, level

---

[198] Rock phosphate is a slow decomposing product and will be readily available to the plants in spring

[199] Plugs are trays of plastic pots called cells.

[200] In French, it is called "Conseil des production vegetales du Quebec" (CPVQ) but the council's name was recently changed to the "Centre de reference en agriculture et agroalimentaire du Quebec" (CRAAQ), which stands for " The center for reference on agriculture and agri-food in Quebec" in English. The guide listed the amounts of nitrogen, phosphorus and potassium required by various crops according to the soil type and fertility levels.

of soil fertility, type of fertilizer compound (solubility & nutrient contents), climate, and plant requirements.

The farm operator usually follows an intuitive approach based on his experience, observation of nutrient deficiency symptoms on the crops and occasionally on soil testing. In organic farms, plant nutrients are mainly provided by compost, green manure[201], organic fertilizers[202] and composted manure. Fresh manure, a rich source of nitrogen, is used by many organic farmers, but is not utilized on the typical farm since many certification agencies in Quebec do not permit that practice (unless they spread it a year earlier on green manure crops). Additionally, crop rotations are designed to take advantage of current soil nutrients and at the same time enrich the soil nutrients.

Compost contains on average 6 kgs of nitrogen, 5 kgs of phosphorus and 6 kgs of potassium per ton[203]. Compost is produced on the farm with some components (manure) brought from neighboring farms[204]. Phosphorus and potassium requirements were supplemented by mineral fertilizers, such as rock phosphate (contains 20-30% P_2O_5) and sulpomag (22% K_2O) for potassium.

The method of fertilizer application depends usually on the soil cover. On bare land, fertilizers are spread and are then incorporated into the soil so as to reduce losses from wind. For established plants, fertilizers are applied either in liquid or solid forms. The ones in liquid forms are either sprayed on the soil or on foliage or through drip irrigation. Solid forms (powdery form), on the other hand, are applied as a side

[201] Green manuring is the practice of turning into the soil un-decomposed plant tissues to enrich the soil with organic matter and nutrients such as nitrogen, phosphates and micro-nutrients. Leguminous crops, when used, have the ability to capture atmospheric and soil nitrogen. In addition, green manure crops also serve as cover crops to protect the soil from erosion, conserve nutrients by capturing it and reduce weed infestation. Some of the common crops planted in Quebec include alfalfa, buckwheat, rye, vetch, clovers, and lupine. Cover crops are usually sown after harvesting the main crop in late summer or early fall, and are then disked and incorporated in the top soil layers (10 cm) around two weeks before planting the main crop in Spring. If used for soil-nutrient building during the regular growing season, the plants are frequently cut to 15 centimeters height and the debris is left on the soil to decompose.

[202] Organic fertilizers are made up of natural ingredients and are void of synthetic chemical substances. Additionally, since most of these compounds have a slow rate of nutrient release, they are believed to be less polluting to the environment. Examples include fish emulsion, blood and feather meals and seaweed mixes.

[203] The availability of nutrients is about 30%, 65% and 90% for nitrogen (N), phosphorus (P2O2) and potassium (K2O) respectively.

dress[205] or just scattered on the soil under the plants' canopy. However when mulch is used, fertilizers are incorporated into the soil before the mulch is laid.

Organic nitrogen fertilizers come in different compounds with different mineral composition and solubility. They are applied to plants using different methods depending on the time of fertilization (i.e. pre or post-emergence etc). Examples of such commonly available compounds include fish emulsion (foliar or soil application), blood meal (soil pre-mix or side dress), bone meal (soil pre-mix), fish and seaweed mix (foliar) and feather meal (soil pre-mix, soil application or side dress). Nitrogen fertilizers are usually applied over several doses in the spring since they are easily leached. Phosphorus compounds, such as rock phosphate, come in less readily available forms (to the plants) and are therefore, incorporated into the soil in the fall. The application of potassium compounds, such as Sulpomag or Basaltic Rock (BioRoche) is usually done in the spring since potassium is leached quickly from the soil (but at a lesser rate than nitrogen).

In the greenhouse, a foliar fertilizer (fish emulsion) is sprayed twice on cabbage and lettuce after germination.

The chemical composition of the some of the commonly used organic fertilizers is listed in Table A3, and the frequency and quantity of fertilizer applications on various crops in the typical farm is shown in Table A4.

Table A3: The Chemical Composition for Some Common Organic Fertilizer Compounds

Compound	Mineral Contents (%N-P-K)*	Application Rate
Fish Emulsion	5-1-1	5 ml / lit. of water
Blood Meal	14-0-0	60 ml / sq. m
Bone Meal	2-11-0	3 gm/ lit. of water
Fish & Seaweed Mix (liquid)	3-2-2	5 ml / liter of water
Feather Meal	13-0.05-0	533 kg / ha
Rock Phosphate	0-25-0	As per plant requirements
Sulpomag	0-0-22 + trace elements	As per plant requirements
Calcium Chloride	(28.5% Calcium)	4 Lit./ha
Limestone		1 ton / ha

*: N-P-K: nitrogen, phosphorus and potassium.

[204] Compost is made from a mixture of beef cattle manure and hay.

[205] Side dressing involves the application of fertilizers close to the crop roots, usually by placing them in a furrow dug along the side of the crop rows

Table A4: The Frequency and Quantity of Organic Fertilizers for Various Crops

	Plot 1 Cabbage	Plot 2 Carrots	Plot 3 Beans	Plot 4 Lettuce	Plot 5 Green Manure
Frequency of greenhouse applications					
Liquid fish & seaweed mix (1)	2			2	
Frequency of field applications					
Liquid fish & seaweed mix	1			1	
Calcium chelate	1			1	
Sulpomag		1			
Feather meal				1	
Limestone	1	1	1	1	1
Quantity of fertilizers applied-greenhouse field (Kg or lit. per plot)					
Liquid fish & seaweed mix (1)	8			8	
Quantity of fertilizers applied in field (Kg or lit. per plot)					
Liquid fish & seaweed mix	16			16	
Calcium chloride	12.8			12.8	
Sulpomag (2)		203.64			
Feather meal				1705.6	
Limestone	3200	3200	3200	3200	3200

Notes:

1) Using a sprayer with a flow rate of 1000 liters/hectare in field and 250 liters/ha of crops in greenhouse. This compound has low nutrient contents, but it is used as a stimulating, stress-reducing spray.
2) The quantity applied is the difference between the quantity applied and that provided by compost, i.e. 14 kg/ha of potassium on carrots.

A.4.4. Pest Control

Since organic certification agencies prohibit the use of synthetic chemicals to control pests and plant diseases, organic production rely on cultural and biological methods. Some of these include: 1) hand picking of large and slow moving insects, 2) use of an aspirator to suck large insects, 3) use of (repellent or sticky) collars at plant base, 4) planting catch crops[206], and 5) proper crop rotations. Biological controls include the use of natural predators (e.g. ladybird beetles to kill aphids) and bacterial inoculants such as Bacillus thuringiensis (BT)[207] and Trichogramma[208]. In addition to these practices, "organic pesticides" such as insecticidal soaps, diatomaceous earth (DE)[209], rotenone[210], and protective fungicides such as copper oxychloride[211], are commonly used.

[206] Catch crops are other crop varieties that are more attractive to the pest insect than the main crop.

[207] This is a bacterial compound that affects the pest insects.

[208] Trichogramma are parasitic insects introduced to control pests like corn borers.

[209] Diatomaceous earth is a powdery compound made u p of crushed skeletons of one-celled plants. The powder sticks to the insects' waxy skeletons and causes it to separate from the insect's main body, subjecting it to die from dehydration. However, the powder is non-selective between beneficial and pest insects.

In the typical farm, the farm operators follow mainly a combination of pro-active and reactive approaches to control pests[212]. The former consisted of rotation of crops from different crop families on the same plot (to break a potential disease cycle) and spraying of (protective) sulfur fungicidal compounds. The reactive approach consisted of removing diseased plants by hand, treating any pests by BT or DT. However, these organic compounds are quite expensive and the farmer uses them as a last resort if other cultural operations do not work[213]. The studied vegetable crops are divided into three categories depending on the level of plant susceptibility to disease and insect/pest infestation. These are low, medium and high susceptibility crops (Table A1). Copper compounds are also applied to seedlings in the greenhouse once every 14 days after germination.

The application rate of the above mentioned compounds as well as the requirements per hectare are listed in Table A5. The frequency of application and quantity needed of these compounds for various crops are shown in Table A6.

Table A5: The Application Rate and Requirements for Organic Pesticides

Compound	Application rate	Requirement per hectare (1)
Rotenone (wettable powder)	10gms/ liter	
Insecticidal soap	1 to 50	
Fungicide (Copper Oxychloride) (1)	4 Kg/1000 liter per ha	4 Kg
Bacillus thurengiensis (1)	4ml/liter	4 Liters
Diatomacious earth	40gms/30 sq. meters	13.33 Kgs

Notes:
1) Using a sprayer with a flow rate of 1000 liters/hectare in field and 250 liters/ha of crops in greenhouse.

210 Rotenone is a broad-spectrum insecticide extracted from plant material.

211 There exists another effective organic pesticide called Pyrethrine, but it is less commonly used in Quebec because of its high price.

212 Organic farmers usually scout pests and intervene only if necessary.

213 In conventional production, farmers follow a protective plan where several chemicals are sprayed at different plant growth stages to prevent any potential fungal of insect infestation.

Table A6: The Frequency and Quantity of Pesticides Required for Various Crops

	Plot 1 Cabbage	Plot 2 Carrots	Plot 3 Beans	Plot 4 Lettuce	Plot 5 Green Manure
Frequency of greenhouse applications					
Mineral Fungicides (Cu)	2			2	
Frequency of field applications					
BT	3				
Mineral Fungicides (Cu)	1	2	1		
Quantity of pesticides applied in GH (kg or lit					
Mineral Fungicides (Cu)	6.4			6.4	
Quantity of pesticides applied in field (kg or lit					
BT	38.4				
Mineral Fungicides (Cu)	12.8	25.6	12.8		

Another major pest are weeds, which are usually controlled by several non-chemical means, namely: 1) manually, using a hoe or a hand driven rotary tiller; 2) mechanically, using a tractor mounted spring-tine hoes, chain harrow or a rotary weeder (the latter is a rolling cultivator that does not go deep into the soil); 3) thermally, with a flame burner; 4) by cultural practices such as a) applying a mulch on the soil, b) using fast growing crop varieties, c) efficient rotation plans, d) cover crops in the fall and winter to disturb weed growth, and by e) additional soil cultivation.

In the typical farm, weed control was done by a combination of means, including mechanical, thermal and manual. One common technique is the stale-bed technique, where the farm operator prepares the soil beds several weeks before the crop planting date giving the weeds ample time to grow, then cultivates the field using a vertical axis rotary cultivator, to remove the weeds. This is particularly used on carrots. The methods of weed control for various crops are listed in Table A7 along with the frequency of operations. Weeding is the most labor intensive operation in organic farming. Time required for manual weeding in cabbage and carrots plots is determined from CREAQ publications for organic crops, which was equivalent to 55 and 250 hours per hectare, respectively.

Table A7: The Frequency & Method of Weed Control for Various Crops

	Plot 1 Cabbage	Plot 2 Carrots	Plot 3 Beans	Plot 4 Lettuce	Plot 5 Green Manure
Equipment for non-manual weeding					
Cultivator, rotary tiller type	1	1			
Finger weeder 4.5 meter wide, wheel mounted	2 (94% of plot)	3	2	1	
Flame weeder, 4 m wide		3			
Spring tine weeder	1 (94% of plot)	2	2	1	
Manual weeding	1	3			

A.4.5. Irrigation Method

Sprinklers are installed and used to irrigate fields during dry periods (usually requires 3 to 4 times per season), while seedlings in the greenhouse are irrigated manually using a sprayer. The source of water is from a well located on the farm as well as from collection ponds located on the farm.

A.4.6. Rotation Plan

Crop rotation plans are primarily designed to break the pest and disease cycle, to contribute to the nutrient buildup in the soil, and/or take advantage of the existing/ current soil nutrients. Therefore, the choice of sequence for the crops depends to a large extent on the crops' rooting systems, nutrient requirements and susceptibility to the same pests. Usually, a rotation is started with crops that contribute to the buildup of soil nutrients, followed by high and then low feeder crops, and the cycle is repeated. Within each category, the rotation starts with crops with short roots followed by deep roots so as to tap into deeper nutrients. The last consideration (in the design of a rotation plan) is to use crops of different (genetic) families so as to break/reduce the pest infestation cycles.

The typical farm is divided into five plots of land each with an area of 3.2 hectares, with a five-year rotation cycle shown in Table A8.

Table A8: Areas of Various Crops under the Rotation Plan

Year	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
1	Fall Cabbage followed by oats (0.2 ha). Winter Cabbage inter-sown with white clover (3 ha)	Carrots	Beans (3.2 ha) , followed by a mixture of oats, peas and common vetch (1.7 ha) and winter rye and hairy vetch (1.5 ha)	Lettuce (3.2 ha) followed by a perennial mixture of red and sweet clover, dactylis orchard grass and rye grass (2.2 ha) & oats (1 ha)	Green manure: same perennial mix on 2.2 ha (plot 4) and red and sweet clover and triticale (1 ha)
2	Carrots	Beans etc	Lettuce etc	Green manure	Cabbage etc
3	Beans etc	Lettuce etc	Green manure	Cabbage etc	Carrots
4	Lettuce etc	Green manure	Cabbage etc	Carrots	Beans etc
5	Green manure	Cabbage etc	Carrots	Beans etc	Lettuce etc

The green manure/cover crops mentioned in year one (first row) are also used in years 2 to 5. The rotation plan will affect the overall farm cash flow, i.e. revenues and expense, over different years.

A.4.7. Harvesting

Cabbage and carrots are harvested mechanically while lettuce and beans are harvested manually at different periods depending on the crops maturity date and cultivar (early, mid season, or late varieties). Cabbage is harvested using a harvester with a front loader while carrots are harvested using a one-row harvester with a lifter blade. Green manure crops are planted using a "Gandy" seeder, which is a box mounted on a spring tine weeder, and are chopped using a home-made chopper. The frequency of harvesting operations is shown in Table A10. The time allocated for manual harvesting is assumed to be the same as the one listed in CREAQ for conventional lettuce.

A.4.8. Labor Requirements

Labor requirements needed to perform various production operations generally depend on the method of production, the equipment used (as performance varies depending on the equipment's width, and time to install and operate), the speed of the tractor and the experience of workers.

To estimate labor time required for various production operations on the typical farm, a detailed listing of all operations made on various plots of land during the year was done. The list also included the machinery/equipment used and frequency of usage. The full listing of machinery/equipment used is shown in Table A9 and the operations performed are shown in Table A10.

The average time required by each machinery/equipment for different operations in a hectare of land was determined from CRAEQ[214] publications (AGDEX numbers 740, 1990 and 740/825, 1992) as well as from consultation with farmers and extension agents. In addition to time required to operate various types of machinery, an extra 20 minutes was allocated to prepare the machinery/equipment and then detach it after each operation. The time needed for manual harvesting and weeding was determined from CREAQ publications for organic production when available, otherwise the

[214] CREAQ stands for " Le comite de references economiques en agriculture du Quebec"; i.e. the Committee for Economic Reference on Agriculture in Quebec. The committee is composed of experts from the Quebec Ministry of Agriculture, Society of Agricultural Credit in Quebec, the Office of the Agricultural Credit in Quebec and the Faculty of Agricultural and Food Sciences at the University of Laval, Quebec City. The committee frequently produces reports on various economic aspects of agriculture, which are published by the Quebec Ministry of Agriculture.

figures listed for conventional production were used. In the greenhouse, it is assumed that five seconds is needed to spray a foliar fertilizer or pesticides on a tray of seedlings. The total labor requirements for production operations on various plots is shown in Table A11.

Table A9: List of Machinery/Equipment Used on the Typical Farm

Machinery or Equipment	Capacity (hours/hectare)
Tractors	
Tractor, 75-80 hp	Variable
Tractor, 35 hp	Variable
Soil preparation machinery	
Chisel 8 tines, tractor mounted, 2 m wide	0.56
Cultivator, heavy tine, 10 feet	0.42
Cultivator, vertical axis rotary (Roterra), 1.5 m wide	0.28
Disk, heavy disk, 8 feet	0.42
Plow, 2-3 shares	1.33
Subsoiler, 1 m wide, tailor made	2.08
Compost preparation & spreading	
Spreader, manure & compost, 3-4 tons	1.00
Turner, compost, with motor	5.00
Seeding & transplanting machinery	
Planter, 2 rows (Lannen)	0.56
Seeder, 2 rows (Stanhay)	0.50
Seeder, Vacuum (greenhouse)	
Gandy box	1.89
Spreading of chemicals	
Sprayer, Chemicals (for 5 beds, 7.5 meters)	
For granular in field	0.16
for liquid in field	0.29
for liquid in GH	
Weeding machinery	
Cultivator, rotary tiller type (for weeding)	0.30
Weeder, finger 4.5 meter wide, wheel mounted	1.89
Weeder, flame 4 m wide	0.31
Weeder, spring type with powder fertiliser box, Gandy, (used also for chemical applic. & some seeding of green manure)	1.89
Harvesting machinery	
Harvester, one row (with Blade lifter for carrots)	4.00
Harvester, one row + front loader (for cabbage)	3.33
Chopper, 1.5 m	5.60

Table A10: Frequency of Operations for Various Crops

	Plot 1-Cabbage		Plot 2-Carrots		Plot 3-Beans		Plot 4-Lettuce		Plot 5-Green Man	
	Frequency	Total Area	Frequency	Total Area	Frequency	Total Area	Frequency	Total Area	Frequency	Total Area
1. No. of GH operations										
Preparation of trays & pots	1						1			
Seeding	1						1			
No of pesticide applications in GH (Sulfur)	1						1			
No of fertilzer applications in GH (2)	2						2			
Others (watering, moving ..etc)										
2. No. of field operations										
Soil preparation										
Chisel 8 tines, tractor mounted, 2 m wide	4	6.4	1	3.2	2	4.7	2	4.2	0	0
Cultivator, heavy tine, 10 feet	1	3	2	6.4	1	3.2	0	0	0	0
Cultivator, vertical axis rotary (Roterra), 1.5 m wide	1	3	3	9.6	0	0	1	3.2	0	0
Disk, heavy disk, 8 feet	2	3.2	1	3.2	1	3.2	2	6.4	0	0
Plow, 2-3 shares	5	6.6	0	0	0	0	1	3.2	0	0
Subsoiler, 1 m wide, tailor made	0	0	0	0	0	0	1	3.2	0	0
Compost preparation & spreading										
Spreader, manure & compost, 3-4 tons										
40 tons/ha	2	3.2	0	0	0	0	0	0	0	0
20 tons/ha	2	3.2	0	0	1	3.2	1	3.2	0	0
Turner, compost, with motor	3	0	0	0	3	0	3	0	0	0
Seeding & transplanting										
Planter, 2 rows (Lannen)	2	3.2	0	0	0	0	1	3.2	0	0
Gandy Weeder - seeder	2	3.2	0	0	2	3.2	2	3.2	1	1
Seeder, 2 rows (Stanhay)	0	0	1	3.2	1	3.2	0	0	0	0
Thining carrots			1	3.2						
Irrigation	5	9.6	5	9.6	5	9.6	5	9.6	0	0
Spreading of chemicals										
Fertilizer, sprayer (for 5 beds, 7.5 meters)	0	0	0	0	0	0	0	0	0	0
Seaweed & Ca Chelate	2	3.2	0	0	0	0	1	3.2	0	0
Sulpomag	0	0	1	3.2	0	0	0	0	0	0
Feather meal	0	0	0	0	0	0	1	3.2	0	0
limestone	1	3.2	1	3.2	1	3.2	1	3.2	1	2.2
rock phospahte	0	0	0	0	0	0	0	0	0	0
Pesticides, Sprayer, (for 5 beds, 7.5 meters)										
BT	6	9.6	0	0	0	0	0	0	0	0
Mineral Fungicides (Cu)	2	3.2	2	6.4	1	3.2	0	0	0	0
Weeding, mechanical										
Cultivator, rotary tiller type (for weeding)	2	3.2	1	3.2	0	0	0	0	0	0
Weeder, finger 4.5 meter wide, wheel mounted	2	6	3	9.6	2	6.4	1	3.2	0	0
Weeder, flame 4 m wide	0	0	3	9.6	0	0	0	0	0	0
Weeder, spring type with powder fertiliser box, Gandy	1	3	2	6.4	2	6.4	1	3.2	0	0
Weeding, manual	1	3.2	3	9.6	0	0	0	0	0	0
Harvesting, mechanical	0	0	0	0	0	0	0	0	0	0
Harvester, one row (with Blade lifter for carrots)	0	0	3	9.6	0	0	0	0	0	0
Chopper, 1.5 m	3	6.2	0	0	1	1.5	1	2.2	3	5.4
Harvester, one row + front loader (for cabbage)	2	3.2	0	0	0	0	0	0	0	0
Harvesting, manual	0	0	0	0	5	16	3	9.6	0	0
Packaging & Handling	1	3.2	1	3.2	1	3.2	1	3.2	0	0

Table A11: Total Labor Requirements for Production Operations in Various Plots

Operation / Plot	Plot 1-Cabbage		Plot 2-Carrots		Plot 3-Beans		Plot 4-Letuce		Plot 5-GM	
	Preparatio	Operat. Tim	Preparatio	Operat. Tim	Preparatio	Operat. Tim	Preparatio	Operat. Tim	Preparatio	Operat. Tim
Greenhouse operations										
Preparation of trays & pots		5.53						7.26		
Seeding	0.33	2.26					0.33	2.96		
Spreading of chemicals	1.00	5.29					1.00	6.94		
Others (watering, moving ..etc)		5.00						5.00		
Field operations										
Land preparation	4.33	15.79	2.33	8.49	1.33	5.29	2.33	16.82	0.00	0.00
Compost spreading	1.33	6.40	0.00	0.00	0.33	3.20	0.33	3.20	0.00	0.00
Seeding & transplanting	1.33	7.84	0.33	1.60	1.00	7.65	1.00	7.84	0.33	1.89
Thining carrots				37.04						
Irrigation	42.66	2.50	42.66	2.50	42.66	2.50	42.66	2.50	0.00	0.00
Spreading of chemicals	3.66	5.15	1.33	2.88	0.67	1.44	1.00	1.95	0.33	0.35
Mechanical weeding	1.67	17.98	3.00	34.21	1.33	24.19	0.67	12.10	0.00	0.00
Manual weeding	0.00	176.00	0.00	800.00	0.00	0.00	0.00	0.00	0.00	0.00
Mechanical harvesting	1.67	45.38	1.00	38.40	0.33	8.40	0.33	12.32	1.00	30.24
Manual harvesting	0.00	0.00	0.00	0.00	0.00	608.00	0.00	278.40	0.00	0.00
Packaging & handling	0.00	880.00	0.00	1856.00	0.00	32.00	0.00	278.40	0.00	0.00
Other operations (5% of above)	2.90	58.76	2.53	139.06	2.38	34.63	2.48	31.78	0.08	1.62
Total Column	**60.87**	**1,233.87**	**53.18**	**2,920.17**	**50.03**	**727.30**	**52.13**	**667.48**	**1.75**	**34.11**
Total No. of hours/plot		**1,294.75**		**2,973.35**		**777.34**		**719.61**		**35.85**

A.4.9. <u>Other Issues</u>

1. Compost is prepared from material partially produced on the farm with beef manure brought from neighboring farms.
2. The selling venues for the produce include sales to wholesalers, organic stores and sometimes to farm visitors.
3. Organic certification is received from the OCIA (Organic Crop Improvement Association) whose standards are the most followed by organic farmers in Canada (Henning, 1994). Representatives from the organization usually make a visit during the initial stages (third year) of conversion to organic production and then make one annual monitoring visit after the start of production.

A.4.10. <u>Other Fixed Assets</u>

In addition to the machinery and equipment listed in Table A-9, the farm also has additional fixed assets as follows: Farm structures, which include a double-layered plastic greenhouse, with a total area of 250 square meters with ventilation, a storage barn for equipment and produce and two cold storage chambers. The greenhouse is heated with a bi-energy system (oil no. 2 and electricity). Other machinery include transportation machinery and equipment for sorting and cleaning the produce. A complete list of used machinery and other fixed assets is shown in Table B13.

A.5. Practices and Main Assumptions for the Conventional Production

For conventional production, the farm operators follow somewhat different practices from that followed for organic. The main difference lies in the lack of a systematic crop rotation and in heavy reliance on synthetic chemicals for pest control and fertilization. Consequently, the process becomes less labor intensive compared to organic production. Since average provincial budgets exist for conventional production, a discussion of production practices will not be done, and it will be assumed that the farm operators follow somewhat similar practices on which to base the costs and revenues.

A.6. Environmental Impacts from Organic Production Practices

Even though organic practices are expected to be less damaging to the environment than conventional ones, they may still cause some negative environmental impacts with either improper management, or uncontrolled factors such as climate, topography, soil characteristics, leaching rates and proximity to rivers among others. In this study, and after consultation with agricultural experts, the following assumption will be made:

1. Soil erosion is assumed to be smaller than the one witnessed under conventional production due to the continuous planting of cover crops and minimal soil disturbance However, yield decrease is assumed to be insignificant due to the systematic soil building with the application of compost and green manure.

2. Compaction: the typical farm is assumed to have a good soil structure due to proper organic matter management, planting of green manure, rotation, less usage of machinery and minimum soil tillage. Still some compaction is expected to occur due to some machinery usage but it is assumed to have a minimal effect on yield. Deep sub-soiling is practiced once every five years.

3. Acidification: since organic production on the typical farm utilizes lime on a yearly basis as part of the soil amendment practices, and the costs are included in the production budget, soil acidification costs will not be accounted for under environmental costs to avoid double counting.

4. Off farm impacts under organic production is assumed to be non-existent since the rate of soil erosion is minimal.

5. No water pollution is assumed to occur under organic production since it uses much less chemicals and in a more conservative manner. In addition, since most organic farmers are typically more aware of the effect or impact of their practices on the environment, manure and compost preparation, storage and application are expected to be done at the right timing, thus minimizing pollution to water bodies.

A.7. Environmental Impacts under the Conventional Production

After consultation with various producers and soil experts between 1995 and 2001, the following assumptions are made to simulate the effects of environmental degradation caused by conventional production practices.

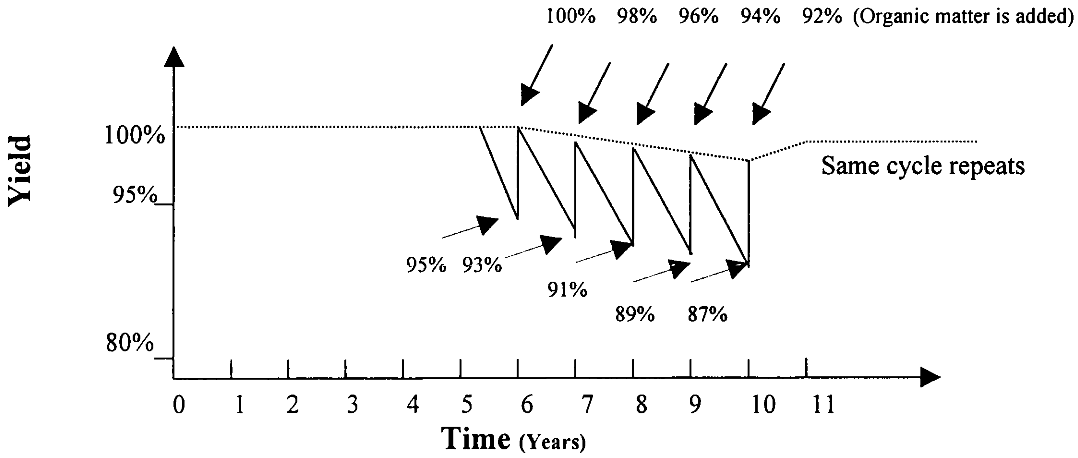
A.7.1. Soil Degradation

1- Soil erosion:

A. All crops have the same decline in crop productivity due to erosion.

B. Yield (productivity) change due to erosion is assumed to decrease by a rate of 5% per year starting from the sixth year (when soil erosion has exceeded the soil tolerance level (T-value). As additional fertilizers are applied at the end of the season to compensate for lost soil, productivity is assumed to return to its initial conditions. However, due to the deterioration of the soil structure, cumulative effects will start to affect the rates of productivity change. Therefore, productivity for years 7 to 10 witness an additional annual decrease of 2% at a linear degradation rate, i.e. productivity decreases by 7%, 9%, 11% and 13% annually for years 7, 8, 9 and 10, respectively. After 10 years, loads of soil rich in organic matter (compost) are added to the land to offset losses and cumulative erosion. The time path of yield is shown in Figure A1.

Figure A1: Time path of yield



C. Productivity decline is assumed to follow the same cycle.

D. Equal amounts of (additional) fertilizers are added each year after the sixth year to compensate for the nutrients lost by erosion. These fertilisers when combined with light soil corrective measures are assumed to potentially enable the soil to increase productivity by about 5% (in the following year).

2- Soil compaction:

A. To repair the effects of soil compaction, subsoiling is done every five years.

B. Compaction is expected to lower yields by 10% per year starting from the second year.

Additional details are discussed in Section 7.2.2.

APPENDIX B

PRODUCTION BUDGETS OF VEGETABLE CROPS IN THE TYPICAL FARM

B.1. Introduction

This section outlines the assumptions and methodologies used to estimate the production costs of the organic vegetable crops produced on the typical farm. The figures are mainly based on the production practices discussed in Appendix A. This section also provides a summary of production budgets of conventionally-produced vegetable crops as reported in the CREAQ publications[215], considered to be the main reference for farmers in the province.

B.2. Production Budget for the Organic Farm

Since there are no published budgets for organically grown crops in Quebec, except for two CREAQ publications on carrots and cabbage in 1990, it was necessary to determine such budgets using primary data based on production practices in the studied (typical) farm, which are designed to represent common practices and average conditions, as discussed in Appendix A.

The budgets cover operating (variable and fixed) costs. These have been divided into five main categories, namely: material, machinery, labour, heating and other items. The latter includes (crop and general) insurance, marketing, advertising, utilities and other related costs. However, the budgets do not include interest or depreciation. The latter is accounted for in the cash flow analysis of the farm operations when performing the CBA analysis. For crop prices, the budget utilises the wholesale farm gate prices.

This section also covers initial or capital costs, which include the costs of land, machinery, equipment and farm structures. These are determined from CREAQ publications and from discussions with agricultural experts.

[215] CREAQ, an abbreviation for the Committee for Economic Reference on Agriculture in Quebec, frequently produces reports on various economic aspects of agriculture. These reports are published by the Quebec Ministry of Agriculture.

Production budgets are reported for each plot of land (3.2 hectares) in 1997-dollar values. This is done to account for the costs of cover/green manure crops, which are grown in-between the main crops at various times of the year, due to their ability to conserve and replenish soil nutrients. Therefore they are considered to be an essential part of the organic production process and their costs have to be accounted for. The total farm cash flow depends on the rotation plan of crops planted in various plots of land.

B.2.1. Material/Input Costs

The prices of production material such as flats, potting media, untreated seeds, organic fertilizers and pesticides have been determined from personal visits and contacts with suppliers in the region of greater Montreal and Laval in 2001. The prices used were regular bulk prices (with no discounts). These prices as well as related technical information such as application and usage rates are listed in Table B1. The total material costs per plot of land (with the same crop) are determined based on the assumptions and formulas listed in the following subsections. The results are summarised in Tables B2, B3, B4 and B5.

Table B1: Prices of Inputs Used in Organic Production and their Usage Rates

Item	Volume/ Weight of Unit	Usage/Application Rate	Unit Price in 1997 C$ values [2]
I. Potting media:			
Pro-mix for seedling trays & pots	0.113 cu m	Fills 22 trays	20.80
2. Potting trays:			
Plug trays (54 x 28 cm)	one unit	128 seeds/tray	0.53
3. Fertilizers:			
Calcium chloride	25 Kgs	4 Lit./ha	20.40
Feather meal (13-0.05-0)	20 kgs	533 kg / ha	23
Fish & seaweed liquid meal (3-2-2) [3]	19 liters	5 ml / liter of water	138
Limestone	1000 kg	1000 kg / ha	30.00
Sulpomag (0-0-22)	20 kgs	As per crop requirements	16.40
4. Pesticides:			
Copper fungicide (copper oxychloride	2 Kgs	4 Kg/1000 liter per ha	26.50
Bacillus thurengiensis compound	0.25 liter	4 ml / liter of water	16.51
5. Seeds: [4]			
Beans (germination rate 100%)	1 kg	88.89 kgs per hectare	5.50
Cabbage (germination rate 75%)	1000 seeds	50,793 seeds per hectare	6.00
Carrots (thin 4/5)	1000 seeds	666,665 seeds per hectare	0.70
Lettuce (germination rate 80%)	1000 seeds	66,666 seeds per hectare	2.00

Item	Volume/ Weight of Unit	Usage/Application Rate	Unit Price in 1997 C$ values [2]
Common vetch	1 kg	20 Kg/ha	3.00
Dactylis orchard grass	1 kg	5 Kg/ha	2.70
Dwarf white clover	1 kg	3 Kg /ha	7.40
Hairy vetch	1 kg	20 Kg/ha	9.7
Oats	1 kg	150 Kg/ha	0.35
Peas	1 kg	30 Kg/ha	0.60
Red clover	1 kg	5 Kg/ha	5.25
Rye grass	1 kg	5 Kg/ha	2.15
Sweet clover	1 kg	5 Kg/ha	3.40
Triticale	1 kg	100 Kg/ha	0.64
Winter rye	1 kg	100 Kg/ha	0.47

Notes:

1) The table lists the lowest prices from the following suppliers: Perron, Cramer, Mckinnes, Plant Products and JVK (Montreal, 2001)
2) Prices were converted to 1997 dollar values using the Farm Input Price Index.
3) The numbers represent percentage composition of nitrogen, phosphorous and potassium respectively
4) Based on crop spacing requirements.

B.2.1.1. **Seed Costs**

The cost of seeds per hectare of various crops was calculated using the following formula:

$$CS = \frac{NP * PS}{AS * GR} \quad \text{OR} \quad CS = \frac{NP * PC}{1000 * GR}$$

Where

CS : cost of seeds ($/hectare)
NP : final number of plants/hectare
PS : price of a kilogram of seeds ($/kg)
PC: price of 1000 seeds
AS : average number of seeds per kilogram
GR : the minimum official germination rate (%) from (Lorenz and Maynard, 1988).
(If the plants are thinned, e.g. carrots, then GR is considered to be 100%).

The cropping plan for cover/green manure crops is shown in Table B2, and the seed costs per plot are shown in Table B3.

Table B2: Area for Various Cover/Green Manure Crops

Cover/green manure crops	Plot 1 Cabbage	Plot 2 Carrots	Plot 3 Beans	Plot 4 Lettuce	Plot 5 * Green Man.
Common vetch			0.57		
Dactylis orchard grass				0.55	
Dwarf white clover	3				
Hairy vetch			0.75		
Oats	0.2		0.57	1	
Peas			0.57		
Red clover				0.55	0.33
Rye grass				0.55	
Sweet clover				0.55	0.33
Triticale					0.33
Winter rye			0.75		

* The plot still has the biennial mix of red and sweet clover, dactylis orchard grass and rye grass planted on 2.2 hectares in the previous year.

B.2.1.2. Potting Media

A commercial potting media made up of a mix of vermiculite, peat moss and lime called "Promix" was used for the transplants. It is usually sold at $18 per bag of 4 cubic feet (0.113 cubic meters). This volume would fill about 22 seedling trays (size 28 by 54 cm). Therefore the volume of potting media needed to fill the trays for the seedlings planted in a hectare or plot of land, is calculated based on the above assumptions, and is shown with the costs in Table B3.

B.2.1.3. Potting Trays

The number of required potting trays is calculated based on the number of cabbage and lettuce seedlings planted in the green house. The number of seedlings is then divided by 128 (since trays have 128 plugs). The total number of required trays and their costs are listed in Table B3.

Table B3. The Quantity and Costs of Some Production Inputs

1. Plant Information	Plot 1 Cabbage	Plot 2 Carrots	Plot 3 Beans	Plot 4 Lettuce	Plot 5 Green Manure
Plant Spacing (inter-row * intra row in meters)	0.75 * 0.35	0.75*0.1	0.75*0.05	0.75*0.25	Variable
Final no. of plants per plot	121,904	426,666	853,331	170,666	
Average seed germination rate (%)	75%	100%	100%	80%	
Thinning	No	Yes, 4/5	No	No	

	Plot 1 Cabbage	Plot 2 Carrots	Plot 3 Beans	Plot 4 Lettuce	Plot 5 Green Manure
2. Seed Requirements & Costs					
Main crops					
No of seeds required/ plot (before thinning)	162,539	2,133,328	853,331	213,332	
No. of seeds per Kg			3000		
Total Kg of seeds required/plot			284.44		
Price of seeds ($/ Kg)			5.5		
Price of seeds ($/1000 seeds)	6	0.7		2	
Total Costs of main crops seeds ($/plot)	**975.23**	**1493.33**	**1564.44**	**426.66**	
Total Costs of cover/GM crops seeds ($/plot)	**77.10**	**0**	**234.87**	**89.63**	**35.75**
3. Potting Trays Requirements & Costs					
No. of trays needed in GH/plot	1,270			1,667	
Costs of trays ($/plot) @ $0.53 each	**673.01**			**883.33**	
4. Potting Media & Costs					
Volume of potting media for trays (cu m/plot)(1)	57.72			75.76	
Total costs of potting media ($/plot)	**1,200.36**			**1,575.48**	

Notes :
1) One bag of Promix contains 0.113 cubic meters (4 cubic feet) and fills 22 trays.

B.2.1.4. Fertilizers Costs

Fertilizers costs are calculated based on the amount of fertilizers applied per plot. The amount is usually a function of plant requirements, length of growing season, time and method of application and the chemical compound used. The latter will have an effect on the frequency and method of application (foliar, side dress etc.). In the typical farm, most of the crop nutrients are supplied from compost, fermented beef manure, green manure crops and some organic fertilizers. Compost is produced on the farm from straw and beef manure purchased from neighbouring farms. The cost of the (compost) ingredients and its transportation is about $25 per ton.

According to the fertilisation plan discussed in section A.4.3, the costs of fertilizers required per plot are listed in Table B4.

Table B4: Costs of Organic Fertilizers for Various Plots

	Plot 1 Cabbage	Plot 2 Carrots	Plot 3 Beans	Plot 4 Lettuce	Plot 5 Green Man.
1- Quantity applied in the GH (Kg or Lit.)					
Liquid fish & seaweed mix	8			8	
2- Quantity applied in the field (Kg or Lit.)					
Liquid fish & seaweed mix	16			16	
Calcium chelate	12.8			12.8	
Sulpomag		203.64			
Feather meal				1705.6	
Compost (tons)	128		64		
Manure (tons)	64			64	
Limestone	3200	3200	3200	3200	3200
5. Costs of fertilisers in GH ($/ plot of plants)					
Liquid fish & seaweed mix	58.11			58.11	
5. Costs of fertilisers in GH ($/plot)					
Liquid fish & seaweed mix	116.21			116.21	
Calcium chelate	10.44			10.44	
Sulpomag		166.98			
Feather meal				1,961	
Limestone	96	96	96	96	96
Total costs of fertilzers in field ($/plot)	222.66	262.98	96.00	2,184.10	96.00
Total costs of fertilzers ($/plot)	**280.76**	**262.98**	**96.00**	**2,242.20**	**96.00**
Total costs of compost & manure ($/plot)	**4,800**	**0**	**1,600**	**1,600**	**0**

B.2.1.5. Pesticides Costs

Pesticides costs were based on the pesticide application program followed in the greenhouse and field plots on the typical farm (section A.4.4). This program identified the type of pesticides used, the frequency and method of application for each of the used organic pesticides. Accordingly, the quantity of pesticides used as well as costs per plot is shown in Table B5.

Table B5: Costs of Organic Pesticides for Various Plots

	Plot 1 Cabbage	Plot 2 Carrots	Plot 3 Beans	Plot 4 Lettuce	Plot 5 Green Man.
1- Quantity applied in the GH (Kg or Lit.)					
Mineral Fungicides (Cu)	6.4			6.4	
2.Quantity applied in field (Kg or Lit.)					
BT	38.4				
Mineral Fungicides (Cu)	12.8	25.6	12.8		
3.Costs of pesticides in GH ($/plot of plants)					
Mineral Fungicides (Cu)	**84.8**			**84.8**	

	Plot 1 Cabbage	Plot 2 Carrots	Plot 3 Beans	Plot 4 Lettuce	Plot 5 Green Man.
4. Costs of Pesticides in GH ($/plot)					
BT	2,535.94				
Mineral Fungicides (Cu)	169.6	339.2	169.6		
Total Costs of pesticides in field ($/plot)	**2,705.54**	**339.20**	**169.60**		
Total Costs of pesticides ($/plot)	**2,790.34**	**339.20**	**169.60**	**84.80**	

B.2.1.6. Summary of Material Costs

Based on the previous calculations, the total material costs for various plots are listed in Table B6.

Table B6: Total Material Costs for Various Plots 1997 Dollar Values

Item	Plot 1 Cabbage	Plot 2 Carrots	Plot 3 Beans	Plot 4 Lettuce	Plot 5 Green Man
Seeds	1,052.33	1,493.33	1,799.31	516.29	35.75
Potting trays in GH	673	0	0	883	0
Potting media in GH	1,200	0	0	1,575	0
Fertilizers	280.76	262.98	96.00	2,242.20	96.00
Compost and manure	4,800	0	1,600	1,600	0
Pesticides	2,790.34	339.20	169.60	84.80	0
Total Costs ($/plot)	**10,796.80**	**2,095.51**	**3,664.91**	**6,902.09**	**131.75**

B.2.2. Labour Costs

Labour costs are calculated based on the total number of man-hours required to perform various production operations (as detailed in section A.4.8). Wages are valued at $8.72 per hour for the year 1997 (Statistics Canada, 2000) including all government-related charges, and the costs of all types of farm work are priced equally. All labour hours are considered to be paid, including the hours put by the farm operator (208 hours per month for seven months) since farm operators may often have an opportunity cost[216]. Additionally, no separate hours are allocated for farm management[217]. The total labour requirements and costs per plot are shown in Table B7.

[216] Farm owner/operators sometimes do not allocate wages for the work they or some of their family members do on the farm (about 8 hours/day per person for 26 days/month) including farm management work. Farmers consider themselves to be self-employed, and their profits are generated from the money and effort invested in farm operations.

[217] It is assumed to be included in the operator's hours.

Table B7: Total Labor Requirements and Costs for Various Plots

	Plot 1 Cabbage	Plot 2 Carrots	Plot 3 Beans	Plot 4 Lettuce	Plot 5 Green Man.
Total No. of hours/plot	1294.31	2973.35	777.34	719.61	35.85
Labor Costs per plot @ $8.72/hr)[1]	8,453.33	19,419.41	5,076.93	4,699.89	234.17

Notes:
1) The farm operator's hours are divided over the five plots proportionally to the hours spent on each plot.

B.2.3. Heating Costs

Heating costs are calculated for the cabbage and lettuce, which are started in the greenhouse. The costs for each crop is based on the area occupied and time spent in the greenhouse. The greenhouse is a joint structure of a total area of 250 square meters. It is covered with double layers of polyethylene plastic, and is heated using a bi-energy system that uses both electricity (60%) and No.2 fuel oil (40%). In 1997, The costs of these were 21.9 cents per kilowatt-hour (G-rate, personal telephone conversation with Hydro-Quebec) and 34 cents per liter, respectively. The temperature of the green house is maintained at 18 degrees Celsius during the night. The amount of energy required to heat the greenhouse is derived from CREAQ publication Agdex No. 717/290, and is shown in Table B8. The total heating costs for various crops are shown in Table B9.

Table B8: Heating Requirements and Costs per Month

	Energy Requirements (1)		Energy Costs (2)		Total Costs
Month	**Electricity (kwh/sq.m)**	**Oil (liter/sq.m)**	**Electricity (cents/sq.m)**	**Oil (cents/sq.m)**	**(cents/sq.m)**
January	44.678	8.28	214.90	181.33	396.23
February	34.318	6.36	165.07	139.28	304.35
March	25.900	4.80	124.58	105.12	229.70
April	13.922	2.58	66.96	56.50	123.46
May	6.151	1.14	29.59	24.97	54.55
June	1.943	0.36	9.34	7.88	17.23
July	0.648	0.12	3.11	2.63	5.74
August	1.619	0.30	7.79	6.57	14.36
September	4.856	0.90	23.36	19.71	43.07
October	13.274	2.46	63.85	53.87	117.72
November	23.634	4.38	113.68	95.92	209.60
December	40.793	7.56	196.22	165.56	361.78
			Yearly Subtotal		**1877.81**

Notes:

1) Energy requirements are extracted from CREAQ's Agdex No. 717/290 (1987) based on a night temperature of 18 degrees Celsius.
2) Costs are based on a bi-energey system using oil No. 2 (40%) and electricity (60%). The energy costs are 21.9 cents kilowatt-hour and 34 cents per liter of oil.

Table B9: Heating Costs for Various Crops

	Beans	Cabbage	Carrots	Lettuce
1. Plant Information				
Start in	Field	GH	Field	GH
Approximate planting date in field		May-07		Jun-07
Total days in GH	0	35	0	28
No. of potting trays/plot		1270		1667
Area in greenhouse (sq.m)		192.02		252.05
2.Days in GH in the Month of				
April		28		
May		7		21
June				7
3. Heating Costs in the Month of *				
April		288.08		
May		31.82		95.47
June				10.05
Total Heating Costs ($/ha)	0	319.91	0	105.52
Total Heating Costs ($/plot of crops)	0	1,023.70	0	337.66

Note:
*: When there is one crop in the greenhouse, all the heating costs are allocated to it.

B.2.4. Operating Machinery Costs

The typical farm uses a variety of machinery and equipment. Some of it was purchased new while some was purchased used, since it was not used on a frequent basis to warrant the high investment. The costs of this machinery along with their performance are shown in Table B10.

Operating machinery costs include the costs of fuel, lubricants, maintenance and repair. The average consumption and costs of fuel used by the farm machinery per an area of land are derived from CREAQ publications AGDEX 763, 740, 740/825 and 740/855. The price of one liter of diesel fuel was $0.45. Lubricant costs are assumed to be equal to 10% of fuel costs, while annual repair and maintenance costs are assumed to be 3% of the machine's initial values. No part of the machinery's initial cost is included in the operating costs[218] to avoid double counting since depreciation is included in the cash flow analysis. An additional 5% of the total operating machinery costs is included to account for miscellaneous machinery used in transportation of harvest from the field to the barns and other minor operations. The operating costs of machinery and their costs per plot are listed in Tables B10 and B11.

Table B10: Operating Costs of Machinery and Equipment

Machinery or Equipment	Purchas-ed status	Price ($)	Diesel fuel usage (lit/ha)	Annual fuel & lubricant costs	Annual repair & mainten-ance costs	Annual TVC ($/ha)*
Tractors & accessories						
Tractor, 75-80 hp	New	37000	Variable			
Tractor, 35 hp	New	22000	Variable			
Soil preparation machinery						
Chisel 8 tines, tractor mounted, 2 m wide	Used	2500	5.44	49.82	75.00	6.75
Cultivator, heavy tine, 10 feet	Used	2500	6.80	42.41	75.00	9.32
Cultivator, vertical axis rotary (Roterra), 1.5 m wide	Used	8000	4.20	32.85	240.00	17.27
Disk, heavy disk, 8 feet	Used	2500	10.90	86.33	75.00	10.08
Plow, 2-3 shares	Used	2500	15.10	73.25	75.00	15.13
Subsoiler, 1 m wide, tailor made	New	500	10.90	17.27	15.00	10.08
Compost preparation & spreading						
Spreader, manure & compost, 3-4 tons	Used	1000	8.00	50.69	30.00	6.30
Turner, compost, with motor	Used	650	8.90	56.39	19.50	5.93
Seeding & transplanting machinery						
Planter, 2 rows (Lannen)	Used	6000	4.78	15.14	180.00	30.49
Seeder, 2 rows (Stanhay)	Used	4000	3.40	10.77	120.00	20.43
Gandy box (to seed green manure)	New	1300	4.20	22.04	39.00	7.41
Spreading of chemicals						
Sprayer For granular	New	9000	1.40	19.27	270.00	10.41
Sprayer for liquid, 7.5 m	New	2500	2.67	29.58	75.00	4.67
Weeding machinery						
Cultivator, rotary tiller type (for weeding)	New	3500	2.20	6.97	105.00	17.50
Weeder, finger 4.5 meter wide, wheel mounted	New	6000	4.20	52.39	180.00	9.22
Weeder, flame 4 m wide	New	2000	2.20	10.45	60.00	7.34
Weeder, spring type with mounted powder fertiliser box (Gandy)	New	4100	4.20	39.50	123.00	8.55
Harvesting machinery						
Harvester, one row (with Blade lifter for carrots)	New	16000	32.40	153.96	480.00	66.04
Harvester, one row + front loader (for cabbage)	New	20000	25.00	39.60	600.00	199.88
Chopper, 1.5 m	New	1100	9.00	68.16	33.00	6.61

Notes:
TVC stands for the total variable costs and is the sum of fuel, oil, repair and maintenance.

[218] Certain budgets include part of the initial machinery costs in the operating costs based on the annual machinery usage rate and operating life of the machine.

Table B11: Total Machinery Time and Costs for Various Plots

Field Operation / Plot	Plot 1-Cabbage	Plot 2-Carrots	Plot 3-Beans	Plot 4-Lettuce	Plot 5-GM
Machinery Time					
Land preparation	15.79	8.49	5.29	16.82	0.00
Compost spreading	6.40	0.00	3.20	3.20	0.00
Seeding & transplanting	7.84	1.60	7.65	7.84	1.89
Spreading of chemicals	5.15	2.88	1.44	1.95	0.35
Mechanical weeding	17.98	34.21	24.19	12.10	0.00
Mechanical harvesting	45.38	38.40	8.40	12.32	30.24
Other operations (5% of total)	5.05	4.40	2.63	2.84	1.62
Total time (hours per plot)	**103.59**	**89.98**	**52.80**	**57.06**	**34.11**
Machinery Costs					
Land preparation	255.05	279.27	93.79	228.80	0.00
Compost preparation & spreading	40.34	0.00	20.17	20.17	0.00
Seeding & transplanting	121.27	65.39	89.08	121.27	7.41
Spreading of chemicals	108.00	96.47	48.24	81.53	22.89
Mechanical weeding	136.97	269.71	113.76	56.88	0.00
Mechanical harvesting	680.59	633.96	9.92	14.55	35.70
Other operations (5% of total)	67.11	67.24	18.75	26.16	3.30
Total costs ($ per plot)	**1409.34**	**1412.05**	**393.71**	**549.36**	**69.30**

B.2.5. Other Operating Costs

There are additional operating costs that are incurred annually, most of which do not depend on the yield, such as the costs of utilities, insurance etc. These are listed in Table B12.

Table B12: Other Annual Operating Costs

Item	Rate	Cabbage ($/plot)	Carrots ($/plot)	Beans ($/plot)	Lettuce ($/plot)	Green Manure ($/plot)	Annual Farm Costs ($)
Annual (organic) monitoring costs by certifying agency		70	70	70	70	70	$350.0
Business insurance (includes Structures & machinery)	5/1000 of initial value	319.1	319.1	319.1	319.1	319.1	$1,595
Crop & hail insurance	Variable based on yield	3432.84	1350.6	479.23	2421.9	0	$7,684
Electricity & heating	$250 / month	600	600	600	600	600	$3,000
Land tax	$40 / year	136	136	136	136	136	$680.
Legal, accounting & other professional fees		400	400	400	400	400	$2,000
Quebec accreditation council fees	5/1000 of gross sales	454.1	279.	114.10	552.96	0	$1,400
Marketing, advertising, storage & transportation costs (1)	proportional to conventional	2093.4	11980.	268.19	8064.	0	$22,406
Repair and maintenance of buildings and fences	3% of initial value	540	540	540	540	540	$2,700.
Telephone	$75 / month	180	180	180	180	180	$900.0

Miscellaneous (2)	3% of farm TVC	4481.21	4481.2 1	4481.2	4481.2	4481.2	$22,406
Total ($/year)		12,706.6	20,336.	7,587.8	17,765	6,726.3	$65,122.

Note:
1) similar to conventional CREAQ budgets
2) Miscellaneous costs include costs of soil testing, consultation fees and other unexpected costs.

It should be noted that interest charges would not be included since they are not part of the cash flow analysis required for CBA analysis.

B.2.6. Fixed Costs / Initial Investment

Initial investment consists mainly of the costs of land, buildings and machinery. The farmland, consisting of a total area of 17 hectares, is valued at $5000 per hectare, i.e. for a total of $85,000. It is assumed that the land is fully paid for, and there are no rent, mortgage or interest to be paid. The final (salvage) value of the land is expected to include an appreciation value of 2% per year. As for machinery/ equipment, in addition to the ones discussed in Section B.2.4, there are additional ones such as the irrigation system and transportation equipment. These are listed in Table B13. This table also shows the costs of buildings and farm structures, such as the greenhouse, storage along with their rates of depreciation. The latter is based on a straight-line method of depreciation.

Table B13: Initial Expenditures and Rates of Depreciation

Item	Initial Price ($)	Depreciation Rate (%)	Annual Depreciation Costs ($)
I. Land (17 ha @ $5000/ha)	85,000	+2% (appreciation)	+1,700 (positive)
II. Buildings & Structures			
Greenhouse, plastic with ventilation (250 sq. m)	15,000	**Plastic: 33.33%** **Structure: 5%**	520 671.9
Storage chambers with refrigeration (2 units)	50,000	**5%**	2,500
Storage barns (used also for packing)	25,000	**5%**	1,250
III. Machinery & Equipment		**10%**	
Total for machinery listed in Table B10	154,650		15,465
Bins, storage (150)	7,500		750
Conveyer belts	3,000		300
Forklift	8000		800
Irrigation Equipment, field	15,000		1,500
Irrigation Equipment, GH	3,200		320
Liquid sprayer (for GH)	750		75
Scales	1,500		150
Tools & maintenance equipment	5,000		500
Truck, 5 tons, with cooling unit (used)	15,000		1,500
Truck, pickup	12,000		1,200
Vacuum seeder (for GH)	500		50

Item	Initial Price ($)	Depreciation Rate (%)	Annual Depreciation Costs ($)
Wagon, harvest * 2	1200		120
Washer, barrel	500		50
Washer, pressure	800		80
Water reservoir	500		50
Total	**404,100**		

B.2.7. <u>Yield</u>

The yield of organically produced crops ranged from 65 to 85% of the conventional produce. The variation from one year to another depended on many factors including soil nutrients, pest infestation, weather, etc. For this study, and after consultations with producers and extension agents, the following yield rates were used: in the case of carrots and cabbage, the same figures published by CREAQ in their organic budgets are used (i.e. carrots 68.6% and cabbage 84.5% of the conventional yield). The conventional yield was determined from CREAQ publications[219]. For lettuce, sine the produce is sold per head and not by weight, the organic figure is assumed to be equal to the conventional one, on the assumption that lower production would be represented in terms of a reduction in the weight per head and not number of heads per hectare. For beans, the organic yield is assumed to be 85% of the conventional one. The average yield per hectare for the crops are listed in Table B14.

B.2.8. <u>Product Prices</u>

The prices used represent the average season (June-December) wholesale prices of organic produce in 1997, derived from major wholesalers in the province (Bio Bulle, 1997). The farmer delivers the produce to the market and therefore, bears transportation costs.

However, it should be noted that prices vary considerably based on the season, market competition, supply and demand, etc., but tend in general, to be about 20-40% higher than that of the conventional produce[220]. The price premium for organic produce over the conventional is mainly the result of both consumer preferences and high demand

[219] The figures of yield reported in CREAQ represent the average of several years.

[220] The price premium for organic produce is highly variable and could range from 20% to 200% for various crops.

for the product, which often, exceeds the quantity supplied. In this study, it is assumed that prices maintain the premium over the period of study, even though it is believed that the price differential is expected to narrow with time as supply increase.

Additionally, these prices are, in general, the result of market mechanisms, and are not the subject of any interference (subsidy or otherwise) in either the input or output markets. The used crop prices are listed in Table B14. Gross revenues per plot are determined by multiplying the yield per plot by the unit price for each crop. These are listed in Table B14.

B.2.9. The Farm Budget

The total costs and revenues per plot for each of the studied crops given the followed rotation plan are listed in Table B14 in 1997-dollar values.

Table B14: Total Organic Crop Budgets for Each Plot in 1997-Dollar Values

	Plot 1 Cabbage	Plot 2 Carrots	Plot 3 Beans	Plot 4 Lettuce	Plot 5 Green Man	Total Farm
Revenues ($/plot)						
Unit of yield	Kg	Kg	Kg	Head		
Yield (units/plot)	105,600	69,760	9,879	138,240		
Price of product ($/unit)	0.86	0.80	2.31	0.8		
Total revenues ($/plot)	**90,816**	**55,808**	**22,821**	**110,592**	0	**280,036.58**
Operating costs ($/plot)						
Material costs	10,796.80	2,095.51	3,664.91	6,902.09	131.75	23,591.07
Labor costs	8,453.33	19,419.41	5,076.93	4,699.89	234.17	37,883.72
Heating costs	0	1,023.70	0	337.66	0	1,361.36
Machinery costs	1403.81	1412.05	388.18	543.83	67.57	3,815.42
Other operating costs (1)	12,706.63	20,336.38	7,587.84	17,765.24	6,726.31	65,122.40
Total operating costs	**33,360.57**	**44,287.05**	**16,717.85**	**30,248.71**	**7,159.80**	**131,773.98**
Gross Revenues ($/plot)	**57,455.43**	**11,520.95**	**6,103**	**80,343.29**	**-7,159.80**	**148,262.60**

Notes:

1- Other operating costs are divided equally over the five plots of land except for crop insurance & Quebec accreditation Council fees, which are a function of revenues of each crop.

For the transition period (first three years), the same organic rotation is used but the product is sold as conventional. Therefore revenues will be affected. The total costs and revenues per plot for the transition period are shown in Table B15 in 1997-dollar values.

Table B15: Total Farm Budget during the Transition Period in 1997-Dollar Values

	Plot 1 Cabbage	Plot 2 Carrots	Plot 3 Beans	Plot 4 Lettuce	Plot 5 Green Man	Total Farm
Revenues ($/plot)						
Unit of yield	Kg	Kg	Kg	Head	0	
Yield (units/plot)	105,600	69,760	9,879	138,240	0	
Price of product ($/unit)	0.23	0.35	0.65	0.52	0	
Total revenues ($/plot)	**24,425**	**24,486**	**6,457**	**72,192**	0	**127,559.98**
Operating costs ($/plot)						
Material costs	10,796.80	2,095.51	3,664.91	6,902.09	131.75	23,591.07
Labor costs	8,453.33	19,419.41	5,076.93	4,699.89	234.17	37,883.72
Heating costs	0.00	1,023.70	0.00	337.66	0.00	1,361.36
Machinery costs	1,403.81	1,412.05	388.18	543.83	67.57	3,815.42
Other operating costs	9,742.98	19,299.35	7,130.10	16,371.32	6,726.31	59,270.06
Total operating costs	**30,396.92**	**43,250.01**	**16,260.11**	**28,854.79**	**7,159.80**	**125,921.63**
Net Revenues ($/plot)	**-5,971.64**	**-18,764.25**	**-9,803**	**43,337.21**	**-7,159.80**	**1,638.35**

B.3. Budgets for Conventionally-Produced Crops

To generate average production budgets for conventionally produced crops in Quebec, the operating variable costs and revenues were derived from CREAQ publications[221]. Two exceptions were made: first, all labor hours are salaried even though CREAQ considers some of the work done by the farm operator and some of his family members to be free. This will insure similar comparison between the organic and conventional scenarios; and second, labor costs were calculated at a constant rate of $8.72 per hour instead of different variable rates. Fixed costs were assumed to be the same as the ones presented for the organic production scenario (except for the organic certification costs). Initial expenditures were also assumed to be the same except for some machinery that was specifically used for organic such as the flame weeder, compost turner and spreader. The crop prices reported in the CREAQ publications were the average for several years. Input prices reported for years other than the 1997-base year, were converted using the Farm Input Price Index. Similarly, output prices were adjusted using the Farm Output Price Index.

To determine the total farm budget, costs and revenues were calculated assuming each crop was planted on four hectare plots. This is to replace the area occupied by the green manure in the organic scenario, which was planted as part of the rotation plan to enrich the soil with nutrients. Since conventional production relies heavily on synthetic chemicals, the area planted with green manure will be equally divided over the remaining four crops[222]. The total farm budget is shown in Table B16.

Table B15: Total Crop Budgets for Each Crop in 1997-Dollar Values

	Plot 1 Cabbage	Plot 2 Carrots	Plot 3 Beans	Plot 4 Lettuce	Total Farm ($)
Revenues ($/plot)					
Unit of yield	Kg	Kg	Kg	Head	
Yield (units/plot)	156,176	127,120	14,528	172,800	
Price of product ($/unit)	0.2313	0.351	0.6536	0.52	
Total Revenues	**36,123.51**	**44619.12**	**9,495.50**	**90240**	**180,478.13**
Operating costs ($/plot)					
Material costs	4,016.00	4,758.36	3,717.24	4,444.00	16,935.60
Labor costs	5,047.67	2,036.78	1,333.35	6,857.21	15,275.00
Heating costs (1)	0.00	1,279.63	0.00	422.08	1,701.70
Machinery costs	392.00	2,896.00	2,612.92	1,160.00	7,060.92
Other operating costs	7,481.61	26,260.89	3,623.09	15,577.61	52,943.21
Total operating costs	**16,937.28**	**37,231.66**	**11,286.60**	**28,460.89**	**93,916.42**
Net Revenues ($/plot)	**19,186.23**	**7,387.46**	**-1,791.10**	**61,779.11**	**86,561.70**

Notes
1) A value of zero means it was not mentioned in CREAQ

[221] The CREAQ publicastions are Beans (Agdex 255/821, 1994), carrots (Agdex 258/821, 1994), lettuce (Agdex 251/821f, 1997) and cabbage (Agdex 252/821f, 1997).
[222] Some rotation of plots may occur but the total area of crop remains the same.

LIST OF REFERENCES

Abdalla, C.W., Roach, B.A. and Epp, D. (1992). Valuing environmental quality changes using averting expenditures: An application to groundwater contamination. *Land Economics*, **68**(2), pp.163-169.

Adler, M.D. and Posner, E.A. (2001). *Cost-benefit analysis, legal, economic and philosophical perspectives*. Chicago: The University of Chicago Press.

Ahmad, Y.J., El Serafy, S. and Lutz, E. (1989). *Environmental accounting for sustainable development*. Washington, DC: The World Bank.

Agriculture Canada. (1985). *Agricultural soil and water resources in Canada: Situation and outlook*. Ottawa, Ontario: Regional Development Branch.

Agriculture Canada (1993). *Soil landscapes of Canada: Quebec-Southeast, Canada soil inventory*. Ottawa, Ontario: Center for Land and Biological Resources Research, Research Branch. Contribution Number 92-195.

Agriculture and Agri-Food Canada. (1999). *Agri-food system overview*. Ottawa, Ontario: Economic and Policy Analysis Directorate. Policy Branch.

Agriculture and Agri-Food Canada. (2001). All about Canada's organic industry. [WWW] *http://www.agr.ca/cb/factsheets/2industry_e.html* (May 2001).

Aldy, J.E. (1998). The role of technology in sustaining agriculture and the environment. *Ecological Economics*, **26**, pp. 81-96.

Alfsen, K.H., Torstein, B. and Lorentsen, L. (1987). *Natural resource accounting and analysis: the Norwegian experience 1978-1986*. Oslo: The Central Bureau of Statistics.

Allen, P., Van Dusen, D., Lundy, J., Gliessman, S. (1991). Integrating social, environmental and economic issues in sustainable agriculture. *American Journal of alternative Agriculture*, **6**, pp.34-39.

Alt, K., Osborn, C.T. and Colacicco, D. (1989). *Soil erosion, what effect on agricultural productivity?* Washington, DC: Economic Research Service. Agriculture Information Bulletin No. 556.

Altieri, M. and Norgaard, R. (1987). *Agroecology: The scientific basis of alternative agriculture*. Boulder, Colorado: Westview Press.

Amir, I., Raghavan, G.S.V., McKyes, E. and Broughton, R.S. (1976). Soil compaction as a function of content pressure and soil moisture content. *Canadian Journal of Agricultural Engineering,* **18**, pp. 54-57.

Anderson M. and Knapik, L. (1984). *Agricultural land degradation in western Canada: A physical and economic overview*. Ottawa: Regional Development Branch. Agriculture Canada.

Andreoli, M., Rossi, R. and Tellarini, V. (1999). Farm sustainability assessment: some procedural issues. *Landscape and Urban Planning*, **46**, pp. 41-50.

Andreoli, M. and Tellarini, V. (2000). Farm sustainability evaluation: methodology and practice. *Agriculture, Ecosystem and Environment*, **77**, pp. 43-52.

Angelson, A. and Sumaila, U.R. (1997). Hard methods for soft policies: Environmental and social cost-benefit analysis. **In**: *Toward sustainable project development* (F. Wilson, ed.), London, (1997: Edward Elgar.

Angus Reid Group. (1990). A *survey of Canadian farmers*. Ottawa: Agriculture Canada. Communications Branch.

Association des fabricants d'engrais du Quebec. (1990). *Guide de Fertilisation*. Quebec.

Azfar, O. (1999). Rationalizing hyperbolic discounting. *Journal of Economic Behaviour and Organization,* **38**(2), pp. 245-252.

Baffoe, J.K., Stonehouse, D.P. and Kay, B.D. (1986). A methodology for farm level economic analysis of soil erosion effects under alternative crop rotational systems in Ontario. *Canadian Journal of Agricultural Economics.* **35, pp.** 55-73.

Bailey, A.P., Rehman, T., Park, J., Keatinge, J.D.H. and Tranter, R.B. (1999). Towards a method for the economic evaluation of environmental indicators for UK integrated arable farming systems. *Agriculture, Ecosystems and Environment*, **72**, pp. 145-158.

Barbier, E.B. (1987). The concept of sustainable economic development. *Environmental Conservation*, **14**(2), pp.101-110.

Barbier, E. B., Markandya, A. and Pearce, D. (1990). Sustainable agricultural development and project appraisal. *European Review of Agricultural Economics,* **17**, pp. 181-196.

Bartik, T.J. (1988). Evaluating the benefits of non-marginal reductions in pollution using information on defensive expenditures. *Journal of Environmental Economics and Management*, **15**, pp.111-127.

Batie, S. (1989). Sustainable development: Challenges to the profession of agricultural economics. *American Journal of Agricultural Economics*, **71**(5), pp.1083-1101.

Batie, S. and Taylor, D. (1989). Widespread adoption of non-conventional agriculture: Profitability and impacts. *American Journal of Alternative Agriculture*, **4**(3), pp.128-134.

Battison, L.A. (1983). *Soil erosion and maize yield in Ontario.* M.Sc. thesis, University of Guelph, Ontario.

Belanger, J.M., Menard, J., Michaud, R., Pelletier, R. and Theriault, J. (1992). *L'avenir de l'agriculture biologique au Quebec*. Quebec: Ministere de l'Agriculture, des Pecheries et de l'Alimentation du Quebec.

Bentham, J. (1983). *Deontology: Together with a table of the springs of action*. Oxford: Clarendon Press.

Bentley, C.F. (1981). Agricultural land degradation summation and perspective. **In**: *Agricultural land: Our disappearing heritage: Proceedings of the 18th annual soil science workshop*. Edmonton, (1981, pp. 393-411.

Bentley, C.F. and Leskiw, L.A. (1983). *An overview of current trends and thinking regarding the sustainability of the productivity of the farmed lands with emphasis on western Canada*. Ottawa: The Canadian Environmental Advisory Council.

Bergstrom, J.C. (1990). Concepts and measures of the economic value of environmental quality: A review. *Journal of Environmental Management*, **31**, pp. 215-228.

Bockstaller, C., Girardin, P. van der Werf, H.M.G. (1997). Use of agro-ecological indicators for the evaluation of farming systems. *European Journal of Agronomy*, **7**, pp. 261-270.

Bosshard, A. (2000). A methodology and terminology of sustainability assessment and its perspectives for rural planning. *Agriculture, Ecosystems and Environment*, **77**, pp. 29-41.

Bouchart, F, Foxon, T., Souter, N., Ashley R., Butler, D. and Jowitt, P. (1998). Decision mapping for the development of multi-criteria analysis tools to assess the relative sustainability of water/wastewater systems. A proposal describing a joint research project between the Heriot-Watt University, Edinburgh, Imperial College, London and University of Abertay, Dundee.

Boulding, K.E. (1981). *Evolutionary economics*. Beverly Hills, California: Sage Publications Inc.

Bowers, J. (1997). *Sustainability and environmental economics: An alternative text.* London: Addison Wesley-Longman.

Briggs, S.A. (1992). *Basic guide to pesticides: Their characteristics and hazards.* Washington, DC: Hemisphere Publishing Company.

Brigham, E.F., Gapenski, L.C. (1996). *Intermediate financial management.* Texas: The Dryden Press.

Bromley, D.W. (1988). Resource and environmental economics: Knowledge, discipline, and problems. **In**: *Agriculture and rural areas approaching the twenty-first century: Challenges for agricultural economics,* Iowa, (1988). (R.J. Hildreth, K.Lipton and K.C. Clayton, ed.), Iowa: Iowa State University Press.

Brouwer, R., Powe, N., Turner, R.K., Bateman, I.J. and Langford, I.H. (1999). Public attitudes to contingent valuation and public consultation. *Environmental Values*, **8**(3), pp. 325-347.

Brundtland, H. (1989). From the cold war to a warm atmosphere. *New Perspective Quarterly*, **6**, pp. 4-8.

Burgoyne, D. (1992). *Analyse economique comparee de l'impact du niveau d'intensification, de l'utilisation d'intrants et de la production biologique sur la rentabilite des enterprises laitieres au Quebec*. Quebec: Universite Laval. M.Sc.Thesis.

Cacek, T. and Lagner, L. (1986). The economic implication of organic farming. *American Journal of Alternative Agriculture*, **1**, pp. 25-89.

Canadian Organic Growers Inc. (1990). *A study of potential market niches for Canadian organic producers*. Ottawa: Agriculture Canada.

Capalbo, S.M. and Antle, J.M. (1989). Incorporating social costs in the returns to agricultural research. *American Journal of Agricultural Economics*, **71**, pp. 458-463.

Carson, R. (1962). *Silent spring*. Boston: Houghton Mifflin.

Checkland, P.B. and Schloes, J. (1990). *Soft systems methodology in action*. Chichester, UK: Wiley.

Christensen, B.T. and Johnston, A.E. (1997). Soil organic matter and soil quality-lessons learned from long term field experiments at Askov and Rothamsted. **In**: *Soil quality for crop production and ecosystem health* (Gregorich, E.G. and Carter, M. R. eds.). Amsterdam: Elsevier.

Clark, E.H., Haverkamp, J. and Chapman, W. (1985). *Eroding soils: The off-farm impacts*. Washington, DC: The Conservation Foundation.

Cobb, D., Feber, R., Hopkins, A., Stockdale, L., O'Riordan, T., Clements, B., Firbank, L., Goulding, K., Jarvis, S. and Macdonald, D. (1999). Integrating the environmental and economic consequences of converting to organic agriculture: evidence from a case study. *Land Use Policy*, **16**, pp. 207-221.

Coker, A. and Richards, C. (1992). *Valuing the environment: Economic approaches to environmental evaluation*. London: Belhaven Press.

Comite de References Economiques en Agriculture du Quebec (CREAQ). (1987). *Legumes en terre noire*. Quebec: Ministere de l'Agriculture, des Pecheries et de l''alimentation du Quebec. Agdex No. 251/821.

Comite de References Economiques en Agriculture du Quebec. (1987). *Pommes de terre*. Quebec: Ministere de l'Agriculture, des Pecheries et de l''alimentation du Quebec. Agdex No. 258/821.

Comite de References Economiques en Agriculture du Quebec. (1989). *Legumes en terre minerale*. Quebec: Ministere de l'Agriculture, des Pecheries et de l''alimentation du Quebec. Agdex No. 252/821.

Comite de References Economiques en Agriculture du Quebec. (1990). *Legumes biologiques*. Quebec: Ministere de l'Agriculture, des Pecheries et de l''alimentation du Quebec. Agdex No. 250/821.

Comite de References Economiques en Agriculture du Quebec. Septembre (1991). *Energie*. Quebec: Ministere de l'Agriculture, des Pecheries et de l''alimentation du Quebec. Agdex No. 760/821. .

Comite de References Economiques en Agriculture du Quebec. (1992*). Horticulture-Statistiques*. Quebec: Ministere de l'Agriculture, des Pecheries et de l''alimentation du Quebec. Agdex No. 200/855.

Conacher, J. and Conacher, A. (1998). Organic farming and the environment, with particular reference to Australia: a review. *Biological Agriculture and Horticulture*, **16**, pp. 145-171.

Conley, B.C. (1976). The value of human life in the demand for safety. *American Economic Review*, **66**, pp. 45-55.

Conway, G. (1997). The green revolution. Food for all in the twenty-first century. Ithaca, New York: Cornell University Press.

Cooper, D.R. and Schindler, P.S. (2001). *Business Research Methods*. Singapore: McGraw-Hill.

Coote, D.R., Dumanski, J. and Ramsey, J.F. (1981). *An assessment of the degradation of agricultural lands in Canada*. Ottawa: Agriculture Canada. Research Branch.

Costanza, R. (1989). What is ecological economics? *Ecological Economics*, **1**, pp.1.

Costanza, R. (1991). *Ecological economics: The science and management of sustainability.* New York: Columbia University Press.

Costanza, R. (1994). Ecological economics and sustainable development. *The International Experts Meeting for the Operationalization of the Economics of Sustainability,* Manila, 1994.

Cox, J. (1988). *How to grow vegetables organically*. Pennsylvania: Rodale Press Inc.

Crews, T.E., Mohler, C.L., Power, A.G. (1991). Energetics and ecosystem integrity: the defining principles of sustainable agriculture. *American Journal of Alternative Agriculture*, **6**, pp. 146-149.

Cropper, M.L., Aydede, S.K. and Portney, P.R. (1994). Preferences for life savings programs: How the public discounts time and age. *Journal of Risk Uncertainty*, **8**, pp. 243-265.

Crosson, P.R. (1982). *The cropland crisis: Myth or reality.* Baltimore, MD: The John Hopkins University Press.

Crosson, P.R. and Stout, A. (1983). *Productivity effects of cropland erosion in the United States*. Baltimore, MD: Resources for the Future and The John Hopkins University Press.

Crutchfield, S., Hansen, L. and Ribaudo, M. (1993). *Agricultural and water quality conflicts: economic dimensions of the problem.* Washington, DC: Economic Research Service. Agriculture Information Bulletin No. 676.

Cummings, R.G., Brookshire, D.S. and Schultze, W.D. (1986). V*aluing environmental goods: an assessment of contingent valuation method.* Totowa, New Jersey: Rowman and Allenheld.

Daly, H.E. and Cobb, J.B. (1989). F*or the common good: redirecting the economy toward community, the environment and a sustainable future*. Boston: Beacon Press.

Daly, H.E. (1994). Fostering environmentally sustainable development: four parting suggestions for the World Bank. *Ecological Economics*, **10**, pp.183-187.

Dasgupta, P. and Maler, K. (1990). The environment and emerging development Issues. *Proceedings of the World Bank Annual Conference on Development Economics* 2, pp.101-152.

De Grandmont, J. (1982). Legere hausse des ventes de la pierre a chaux agricole. *Agri-Chaux Nouvelles*, **3**(1), pp.1-2.

DEPA. The Danish Environmental Protection Agency. (1999*). Okologiske scenarier for Denmark.* Copenhagen: Denmark.

Dissart, J.C., Baker, L. and Thomassin, P.J. (2000). The economics of erosion and sustainable practices: the case of the Saint-Esprit Watershed. *Canadian Journal of Agricultural Economics*, 48, pp. 103-122.

Dixon, J.A. and Hufschmidt, M.M. (1986). *Economic valuation techniques for the environment: a case study workbook.* London: East-West Environment and Policy Institute and The John Hopkins University Press.

Dixon, J.A., Scura, L.F., Carpenter, R.A. and Sherman, P.B. (1994*). Economic analysis of environmental impacts*. London: Earthscan.

Dobbs, T.L., Leddy, M.G. and Smolik, J.D. (1988). Factors influencing the economic potential for alternative farming systems: case analyses in South Dakota. *American Journal of Alternative Agriculture*, **3**, pp. 26-34.

Domanico, J.L., Madden, P. and Partenheimer, E.J. (1986). Income effects of limiting soil erosion under organic, conventional, and no till systems in eastern Pennsylvania. *American Journal of Alternative Agriculture*, **1**, pp. 75-82.

Dreze, J.P. (1998). Distribution matters in cost-benefit analysis: Comment on K.A. Brekke. *Journal of Public Economics*, **70**, pp. 485-488.

Eckholm, E. and Brown, L.R. (1977). *Spreading deserts-the hand of man.* Washington, DC: Worldwatch.

Ecological Agriculture Projects. (1982). *Mulching: why mulch?* Sainte Anne de Bellevue, Quebec. Publication No. 5/82.

Ecological Agriculture Projects. (19--). *Composting : why compost*? Sainte Anne de Bellevue, Quebec. Publication No. 56.

Ecological Agriculture Projects. (19--). *La production biologique de la tomate en serre telle que pratiquee par les produits biologiques.* Sainte Anne de Bellevue, Quebec: La Fee Inc., Service d'Information Agro-Bio.

Ecological Agriculture Projects. (19--). *Common garden pests.* Sainte Anne de Bellevue, Quebec.

Ekins, P. (1986). The living economy: a new economics in the making. London: Routledge and Paul Kegan.

El-Hinnawi, E. (1982). *Global environmental issues.* Dublin: Tycology International Publication Limited. Natural Resources and Environmental Series, volume 7.

El-Serafy, S. and Lutz, E. (1989). Environmental and resource accounting. **In:** E*nvironmental accounting for sustainable development. A UNEP-World Bank symposium* (Y.J. Ahmad, S. El Serafy and E. Lutz. ed.). Washington, DC: The World Bank.

El Titi, A., Boller, E.F. and Gendrier, J.P. (1993). Integrated production. Principles and technical guidelines. *IOBC/WPRS Bulletin*, **16**, pp. 13-38.

Emond, G. (19--). *Communique.* Quebec: Agriculture Quebec.

Environment Canada. (1982*). Agricultural land use change in Canada.* Ottawa: Lands Directorate. Catalogue No. 73-1/21E.

Environment Canada. (1999). *The contribution of agricultural activities to the deterioration of the St. Lawrence River.* Ottawa. Catalogue No.: En153-97/1999-4-1E.

Environnement Quebec. (1988a). *L'environnement au Quebec, un premier bilan: document technique.* Quebec.

Environnement Quebec. (1988b). *L'environnement au Quebec. Un premier bilan: synthese.* Quebec.

Environnement Quebec. (1989). C*ode de gestion des pesticides: version provisoire. Document de consultation.* Quebec.

Extoxnet. (1993). *Pesticide information notebook.* Oregon: Oregon State University.

Faeth, P., Repetto, R., Kroll, K., Dai, Q. and Helmers, G. (1991). *Paying the farm bill: U.S. agricultural policy and the transition to sustainable agriculture.* Washington, DC: World Resources Institute.

Faeth, P. (1993). *Agricultural policy and sustainability: case studies from India, Chile, the Philippines and the United States.* Washington, DC: World Resources Institute.

Farrow, S. and Toman, M. (1999). Using benefit-cost analysis to improve environmental regulations. *Environment*, **41**(2), pp.12-21.

Foebus, A. (1991). Experiences alternatives de mise en marche. In: C*olloque sur la mise en marche des produits biologiques.* Institut de technologie agro-alimentaire de la Pocatiere. Quebec: Union des Producteurs agricoles.

Folmer, H. and Van Ierland, E. (1989*). Valuation methods and policy making in environmental economics.* Amsterdam: Elsevier. Studies in Environmental Science No. 36.

Fox, M.G. and Coote, D.R. (1986). *A preliminary economic assessment of agricultural land degradation in Atlantic and Central Canada and Southern British Columbia.* Ottawa: Agriculture Canada. Agriculture Development Branch.

Fox, M.G. and Dickson, E.J. (1989*). What's economic about the economic costs of erosion to Canadian farmers.* Guelph, Ontario: University of Guelph. Department of Agricultural Economics and Business. Discussion Paper No. DP88/3.

Fox, M.G. and Dickson, E.J. (1990). The economics of soil erosion and sediment control in south-western Ontario. *Canadian Journal of Agricultural Economics*, **38**, pp. 23-44.

Foy, G.E. (1991). Accounting for non-renewable natural resources in Louisiana's gross state product. *Ecological Economics*, **3**, pp. 25-41.

Girardin, P., Bockstaller, C. and van der Werf, H. (2000). Assessment of potential impacts of agricultural practices on the environment: the Agro-Eco method. *Environmental Impact Assessment Review*, **20**, pp. 227-239.

Giroux, L. (1995). *Contamination de l'eau souterraine par les pesticides et les nitrates dans les regions de culture de pomme de terre: campagnes d'echantillonnage de (1991-1992-1993).* Quebec: Environment Quebec.

Giroux, I., Duchemin, M. and Roy, M. (1997). *Contamination de l'eau par les pesticides dans les regions de culture intensive du mais au Quebec: campagnes d'echantillonnage de 1994 et 1995).* Quebec: Environment Quebec.

Glasson, J., Therival, R. and Chadwick, A. (1994). *Introduction to environmental impact assessment.* London: UCL Press.

Hall, J.V., Winer, A.M., Kleinman, M.T., Lurmannn, F.W., Brajer, V. and Colome, S.D. (1992). Valuing the health benefits of clean air. *Science*, **255**, pp. 812-817.

Hanisch, S. (1990). *The organic products market in Montreal.* Montreal: McGill University. The Department of Agricultural Economics.

Hanley, N. (1990). The economics of nitrate pollution. *European Journal of Agricultural Economics*, **17**, pp. 129-151.

Hanley N. and Spash, L. (1993). *Cost-benefit analysis and the environment.* London: Edward Elgar Publishing.

Hansen, B., Alroe, H.F. and Kristensen, E.S. (2001). Approaches to assess the environmental impact of organic farming with particular regard to Denmark. *Agriculture, Ecosystems and Environment*, **83**, pp. 11-26.

Haufkamp, W.A. (1984). *Economic-environmental modelling in a national -regional system.* Amsterdam: Elsevier Science Publishers. Studies in Regional Science and Urban Economics No. 10.

Helmers, G.A., Langemeier, M.R. and Atwood, J. (1986). An economic analysis of alternative cropping systems for east central Nebraska. *American Journal of Alternative Agriculture*, **1**, pp.153-158.

Henderson, H. (1981). *The politics of the new solar age: alternatives to economics.* New York: Anchor Books.

Henning, J.C., Thomassin, P.J. and Baker, L. (1990). *Organic farmers in Quebec: results of a survey.* Montreal: McGill University, Department of Agricultural Economics.

Henning, J.C. (1994). Economics of organic farming in Canada. **In**: *The economics of organic farming: an international perspective* (N.H. Lampkin and S. Padel, ed.), pp. 143-160. Wallingford: CAB International.

Hill, S.B. (1975). Composting for farm and garden: the whys and wherefores and how to do it. *Macdonald Journal,* **36**(11), pp. 6-20. Ste. Anne de Bellevue, Quebec.

Hill, S.B. and MacRae, R.J. (1992). Organic farming in Canada. *Agriculture, Ecosystems and Environment*, **39**, pp.71-84.

Hoar, S.K., Blair, A., Holmes, F.F., Boysen, C.D., Robel, R.J., Hoover, R. and Fraumeni, J.F. (1986). Agricultural Herbicide Use and Risk of Lymphoma and Soft-Tissue Sarcoma. *Journal of American Medical Association*, **256**(9), pp. 1141-1147.

Hodgson, T. A. and Meiners, M.R. (1982). Cost of illness methodology: a guide to current practices and procedures. *Milbank Memorial Fund Quarterly*, **60**(3), pp. 429-462.

Howse, K.D. and Coote D.R. (1984). *Agriculture et conservation de l'environnement.* Ottawa: Agriculture Canada. Institut de Recherches sur les Terres. Publication # IRT 83-56.

Hueting, R. (1991). The use of the discount rate in a cost-benefit analysis for different uses of a humid tropical forest area. *Ecological Economics*, **3**, pp. 43-57.

Hufschmidt, M.M. and Hyman, E. 1982. Economic Approaches to Natural Resource and Environmental Quality Analysis. **In**: *Proceedings and Papers of a Conference on Extended Cost-Benefit Analysis, the Environment and Policy Institute, East-West Center*, Honolulu, Hawaii, September (1979). Dublin: Tycology International Publishing Limited.

Hufschmidt, M.M., James, D.E., Meister, A.D., Bower, B.T. and Dixon, J.A. (1983). *Environment, natural systems, and development: an economic valuation guide*. Baltimore, MD: The John Hopkins University Press.

Hyman, E. L. (1981). The valuation of extra-market benefits and costs in environmental impact assessment. *Environmental Impact Assessment Review*, **2**(3), pp. 27-264.

Ikerd, J. (1993). Two related but distinctly different concepts: organic farming and sustainable agriculture. *Small Farm Today*, **10**(1), pp. 30-31.

Institut de la Statistique du Quebec. (2001). *Comptes economiques du Quebec, 1er trimestre 2001*. Quebec: Direction des comptes et des etudes economiques.

Institute of Arable Crops Research (IACR). (2002). *Compound Indicators*. Agriculture and the Environment Division. Herts: UK. [WWW]. http://www.iacr.bbsrc.uk/aen/statistics/uniquaims/aen_guideline3.html (September 2002).

International Federation of Organic Agriculture Movements (IFOAM). (1998). *Basic standards for organic production and processing*. Tholey-Theley, Germany: IFOAM.

International Institute for Sustainable Development (IISD). (1999). Aggregated indices. Consultative Group on Sustainable Development Indicators, Canada. [WWW] *http://www.iisd.org/cgsdi/indices.htm* (September 2002).

Irwin, D. (1994). Personal Conversation.

Jacobs, M. (1995). Sustainable development – from broad rhetoric to local reality. **In**: *Conference proceedings from Agenda 21*, Cheshire, December 1994. Cheshire County Council. Document No. 493.

Jansen, K. (2000). Labour, livelihoods and the quality of life in organic agriculture in Europe. *Biological Agriculture and Horticulture*, 17, pp. 247-278.

Jones, C.A., Dyke, P.T., Williams, J.R., Kinery, J.R., Bensen, V.W. and Griggs, R.H. (1991). EPIC: an operational model for evaluation of agricultural sustainability. *Agricultural Systems*, **35**, pp. 341-350.

Kelly, T.C., Lu, Y.C. and Teasdale, J. (1996). Economic-environmental tradeoffs among alternative crop rotations. *Agriculture, Ecosystems and Environment*, **60**, pp.17-28.

Kirchmann, H. and Thorvaldsson, G. (2000). Challenging targets for future agriculture. *European Journal of Agronomy*, **12**, pp. 145-161.

Kirkpatrick, C. and Lee, N. (1997). *Sustainable development in a developing world: integrating socio-economic appraisal and environmental assessment.* London: Edward Elgar Publications.

Knisel, W.G. (1980). *CREAMS: a field scale model for chemicals, runoff and erosion from agricultural management systems*. Washington, DC: The U.S. Department of Agriculture. Conservation Research Report No. 26.

Knoblauch, W.A., Brown, R. and Braster, M. (1990). *Organic field crop production: a review of the economic literature*. Ithaca, NY: Cornell University, Department of Agricultural Economics.

Kontogianni, A., Skourtos, M.S., Langford, I.H., Bateman I.J. and Georgiou S. (2001). Integrating stakeholder analysis in non-market valuation of environmental assets. *Ecological Economics*, **37**(1), pp. 123-138.

Lamarche, A. (1992). *Qualite de l'eau: consommation humaine directe. Evaluation de la qualite de l'eau du fleuve Saint-Laurent, Troncon Cornwall-ile d'Orleans, entre (1978-1988).* Montreal: Direction de la connaissance de l'etat de l'environment, Centre Saint Laurent.

Lampkin, N. (1985). Profitability of organic farming systems. A paper presented at the University College of Wales Agricultural Society Conference. Aberystwyth, Wales.

Lampkin, N. (1986). A research concept for investigating organic farming systems: case studies. **In**: *Proceedings of the IFOAM Conference*, Santa Cruise, California. pp. 121-134.

Lampkin, N. (1990). *Organic farming*. Ipswich: Farming Press Books.

Lampkin, N. (1993). *The economic implications of conversion from conventional to organic farming systems*. PhD Thesis. University of Wales, Aberystwyth.

Lampkin, N. and Padel, S. (1994). *The economics of organic farming: an international perspective*. Wallingford: CAB International.

Lampkin, N. and Measures, M. (1995). *1995/96 organic farm management handbook.* Aberystwyth, Wales: University of Wales Elm. Farm Research Center.

Lampkin, N. (1998). Organic livestock production and agricultural sustainability. **In**: *Resource use in organic farming* (eds. J. Isart and J. J. Llerena). ENOF, Barcelona. pp 321-330.

Leclerc, B. (1992). Le developpement de l'agriculture biologique au Quebec : un grand pas vers une agriculture durable. *Nature et Progres*. Mars/Avril 1992. pp. 18-21. Quebec.

Lefroy, R.D., Bechstedt, H. and Rais, M. (2000). Indicators for sustainable land management based on farmer surveys in Vietnam, Indonesia and Thailand. *Agricultural Ecosystems and Environment*, 81, pp. 137-146.

Leontief, W. (1970). Environmental repercussions and economic structure: an input-output approach. *Review of Economical Statistics*, **52**, pp. 262-271.

Little, I.M.D. and Mirrlees, J.A. (1974). *Project appraisal and planning for the developing countries*. London: Heinemann Educational Books.

Lockeretz, W. (1982). *Environmentally sound agriculture*. New York: Praeger.

Lockeretz, W. (1989). Comparative local economic benefits of conventional and alternative cropping systems. *American Journal of Alternative Agriculture*, **4**, pp.75-83.

Lorenz, O.A. and Maynard, D.N. (1988). *Handbook for vegetable growers*. 3rd ed. New York: Wiley-Interscience Publication.

Lutz, E. (1993). *Toward improved accounting for the environment*. Washington, DC: The World Bank.

Lutz, E., Pagiola, S. and Reiche, C. (1994). *Economic and institutional analyses of soil conservation projects in central America and the Caribbean*. Washington, DC: The World Bank, Environment Paper No. 8.

MacNeill, J. (1989). Strategies for sustainable economic development. *Scientific American*, **261**(3), pp.155-165.

MacRae, R.J., Henning, J. and Hill, S.B. (1988). *Financing organic sustainable agriculture*. Ste. Anne de Bellevue, Quebec: Ecological Agriculture Projects. Research Paper No. 5.

MacRae, R.J., Mehuys, G.R., Hill, S.B., and Henning, J. (1989). Farm scale agronomic and economic conversion to sustainable agriculture. *Advances in Agronomy*, **43**, pp. 155-189.

MacRae, R.J. (1991). *Strategies to overcome agribusiness barriers to the development of sustainable agriculture in Canada*. Ste. Anne de Bellevue, Quebec: Ecological Agriculture Projects. Paper No. .

Madden, P. (1996). Posting to the Sanet-Management of Sustainable Agriculture Internet Discussion List, 14 February, 1996.

MAPAQ (Ministere de l'Agriculture, des Pecheries et de l'Alimentation du Quebec, in English: Ministry of Agriculture of Quebec). (1993). *La Situation et le developpement de L'agriculture biologique au Quebec: document synthese*. Quebec.

MAPAQ. (1998). *An overview of the Quebec biofood industry*. Quebec.

Markandya, A. (1994). *Policies for sustainable development: four essays*. Rome: FAO. Development paper No. 121.

Markandya, A. (1998). *Methodology for evaluating environmental damages over time and the progressive benefits of prevention and mitigation: application to the mining, mineral processing and the metallurgy industries*. Bath: University of Bath. Issues paper.

Markandya, A. and Pearce, D. (1988). *Environmental considerations and the choice of the discount rate in developing countries*. Washington, DC: The World Bank. Environment Department. Working paper No.3.

Markandya, A. and Pearce, D. (1991). Development, environment and the rate of discount. World Bank Research Observer.

Marks, R. and Ward, J. (1993). *Nutrient and pesticide threats to water quality*. Washington, DC: Natural Resources Defence Council.

Masse. L. (1990). *The leaching of metolachlor, atrazine, and two atrazine metabolites in two corn fields in Quebec*. Montreal: McGill University. Department of Agricultural Engineering.

McAllister, D.M. (1980). *Evaluation in environmental planning: assessing environmental, social, economic, and political trade-offs*. Cambridge, Massachusetts: MIT Press.

McDaniels, T. (1991). Public sector perspectives on renewable energy economics. **In**: *Guidelines for the economic analysis of renewable energy technology* (, ed.), pp.158-162. Quebec.

Mckinney, T.R. (1987). *Comparison of organic and conventional agriculture: a literature review*. Snowmass, Colorado: Rocky Mountain Institute.

McRobie, G. (1990). Tools for organic farming*: a manual of appropriate equipment and treatments*. London: Intermediate Technology Publications.

McKyes, E., Negi, S., Douglas, E., Taylor, F. and Raghavan, G.S.V. (1979). The effect of machinery traffic and tillage operations on the physical properties of clay and on yield of silage corn. *Journal of Agricultural Engineering Research*. **24**(2), pp.143-148.

Mehuys, G.R. (1984). *Degradation of agricultural lands in Quebec: a review and impact assessment*. A report presented to the Science Council of Canada. Ottawa.

Merrifield, J. (1997). Sensitivity analysis in benefit-cost analysis. *Contemporary Economic Policy*, **15**(3), pp.82-92.

Meyers, C.F., Meeks, J., Tuller, S. and Weinberg, A. (1985). Non-point sources of water pollution. *Journal of Soil and Water Conservation*, **40**, pp.14-18.

Midmore, P. (1994). Input-output modelling of organic farming and the rural economy of England and Wales. **In**: *The economics of organic farming: an international perspective (eds* Lampkin, N. and Padel, S.). Wallingford: CAB International

Midmore, P. and Whittaker, J. (2000). Economics for sustainable rural systems. *Ecological Economics*, **35**, pp. 173-189.
Midmore, P., Padel, S., McCalman, H., Isherwood, J., Fowler, S. and Lampkin, N. (2001). *Attitudes towards conversion to organic production systems: A study of farmers in England.* Aberystwyth, Wales: University of Wales. Institute of Rural Studies.

Milne, M. (1996). On sustainability; the environment and management accounting. *Management Accounting Research*, **7**, pp.135-161.

Ministere de l'Environnement (In English: Ministry of Environment). (1992). *Contamination du milieu aquatique et des eaux souterraines par les pesticides au quebec: revue des differentes activites d'echantillonnage realises de (1980 a 1991).* Sainte Foy, Quebec: Direction du Milieu Agricole et du Controle des Pesticides.

Ministere de l'Environnement. (1993). *Contamination de l'eau souterraine par l'aldicarbe dans les regions de culture intensive de pommes de terre (1984 a 1991).* Sainte Foy, Quebec: Direction du Milieu Agricole et du Controle des Pesticides.

Mishan, E. J. (1982). *Cost-benefit analysis.* New York: Praeger Publishers.

Morvaridi, B. (1994). Sustainable development and project appraisal. **In**: *The economics of project appraisal and the environment* (J. Weiss, ed.). London: Edward Elgar Publications.

Munasinghe, M. (1993). *Environmental economics and natural resource management in developing countries.* Washington, DC: The International Bank for Reconstruction and Development. Committee of International Development Institutions on the Environment.

Munasinghe, M and Lutz, E. (1993). *Environmental economics and valuation in development decision-making.* Washington, DC: The World Bank. Environment Working Paper No. 51.

Myers, R.J.K., van Noordwijk, M. and Vityakon, P. (1997). Synchrony of nutrient release and plant demand: plant litter quality, soil environment and farmer management options. **In**: *Driven by nature. Plant litter quality and decomposition* (Cadisch, G. and Giller, K.E. eds.) Wallingford, UK: CAB International.

Nambiar, K.K., Gupta, A.P., Qinglin, F. and Li, S. (2001). Biophysical, chemical and socio-economic indicators for assessing agricultural sustainability in the Chinese coastal zone. *Agriculture, Ecosystems & Environment.* 87(2), pp. 209-214.

National Research Council. (1986). *Pesticides and ground water quality: issues and problems in four states.* Washington DC: National Academy Press.

National Research Council. (1989). *Alternative agriculture.* Washington DC: National Academy Press.

Navrud, S. (1994). Economic valuation of external costs of fuel cycles: testing the benefit transfer approach. **In**: *Models for integrated electricity resource planning* (A. T. de Almeida ed.). Kluwer Academic Publishers.

Neumayer, E. (1999). *Global warming: discounting is not the issue, but substitutability is. Energy Policy*, **27**(1), pp.33-43.

Nicks, A.D., Burt, J.B., Knisel, W.G. and Gandar, G.A. (1984). *Application of a field scale water quality model for evaluation of watershed land treatment project*. St. Joseph, MI: American Society of Agricultural Engineers. Paper No. 84-2633.

Nielson, E.G. and Lee, L.K. (1987). *The magnitude and costs of groundwater contamination from agricultural chemicals*. Washington, DC: Economic Research Services. Agricultural Economics Report No. 576.

Nijkamp, P., Rietveld, P. and Voogd, H. (1990). *Multicriteria evaluation in physical planning*. Amsterdam: North Holland.

Nimmo, T.L. (1991). *Directory of organic agriculture*. Second Edition. Ottawa: Canadian Organic Growers Inc.

Norgaard, R.B. (1991). Sustainability: the paradigmatic challenge to agricultural economics. *Workshop on Sustainable Agriculture: Economic Perspectives and Challenges.* Winnipeg, Manitoba.

Norgaard, R.B. (1991b). *Sustainability as intergenerational equity: the challenge to economic thought and practice*. Washington, DC: The World Bank. Internal Discussion Paper. Asia Regional Series. Report No. IPD 97.

Northbourne, L. (1940). *Look to the land.* London: J.M. Dent.

Nyborg M. and Hoyt, P.B. (1978). Effects of soil acidity and liming on mineralization of soil nitrogen. *Canadian Journal of Soil Science*, **58**, pp. 331-338.

OECD. (1997). *Environmental indicators for agriculture*. Paris, France.

Oelhaf, R.C. (1987). *Organic agriculture: economic and ecological comparisons with conventional methods*. Montclair: Allanheld, Osmun and Company Publishers.

Offermann, F. and Nieberg, H. (2000). Economic performance of organic farms in Europe. *Organic Farming in Europe: Economics and Policy.* Volume 5. Hohenheim, Germany: The University of Hohenheim.

Ogilvy, S.E., Turley, D.B., Cook, S.K., Fisher, N.M., Holland, J., Prew, R. and Spink, J. (1994). Integrated farming. Putting together systems for farm use. *Aspects of Applied Biology*, **40**, pp. 53-61.

Olson, R.K. (1998). *Procedures for evaluating alternative farming systems: A case study for Eastern Nebraska.* Extension and education materials for sustainable agriculture: Volume 8. Center for Sustainable Agricultural Systems, University of Nebraska-Lincoln.

Otis, T. and Fournier, F. (1989). *Priorites de recherche en agriculture biologique.* Quebec: Agriculture Canada. Direction General de la Recherche, Section de L'est.

Padel, S. and Zerger, U. (1994). Economics of organic farming in Germany. **In**: *The economics of organic farming: An international perspective.* (Lampkin, N. and Padel, S. Eds.). Wallingford, UK: CAB International.

Page, T. (1978). A generic view of toxic chemicals and similar risks. *Ecology Law Quarterly*, **7**, pp. 207-244.

Pagiola, S. (1994). Cost-benefit analysis of soil conservation. **In**: *Economic and institutional analyses of soil conservation projects in Central America and the Caribbean* (The World Bank ed.). Washington, DC: The World Bank.

Patriquin, D., Edwards, L, Gimby, M., Jobin, P., and Samson, R, (1991). *Seven case studies in sustainable agriculture.* A report to the Science Council of Canada.

Pearce, D. (1978). *The valuation of social cost.* London: Allen and Unwin.

Pearce, D. (1987a). *Economic values and the natural environment.* Denman lecture at the Department of Land Economy, University of Cambridge, London.

Pearce, D. (1987b). Foundations of an ecological economics. *Ecological Modelling.* **38**, pp. 9-18.

Pearce, D. (1989). *Sustainable development and economic perspective.* London: London Environmental Economics Center. International Institute for Environment and Development. Gate Keeper Series No. 89-01.

Pearce, D. (1997). Integrating environment into development planning: where have we got to? **In**: *Toward sustainable project development* (F. Wilson ed.). London: Edward Elgar Publishing.

Pearce, D., Barbier, E. and Markandya, A. (1988). Sustainable development and cost-benefit analysis. *Workshop on integrating economic and environmental assessment. The Canadian Environmental Research Council.* Vancouver, Canada. November 1988.

Pearce, D. and Warford, J.J. (1993). *World without end: economics, environment, and sustainable development.* London: Oxford University Press.

Percival, B. (1984). *Organic vegetable gardening.* Pennsylvania: TAB Books Inc.

Petry, F. (1990). Who is afraid of choices? A proposal for multi-criteria analysis as a tool for decision-making support in development planning. *Journal of International Development*, **2**(2), pp. 209-231.

Pham, T., Kum, K. and Lemieux, C. (1996). Seasonal variation of DDT and its metabolites in the St. Lawrence River (Canada) and four of its tributaries. *The Science of the Total Environment*, **179**, pp. 17-26.

Philibert, C. (1999). The economics of climate change and the theory of discounting. *Energy Policy*. **27** (15), pp. 913-927.

Phipps, T.T., Crosson, P.R. and Price, K.A. (1986). *Agriculture and the environment. Annual policy review*. Washington, DC: Resources for the Future. The National Center for Food and Agricultural Policy..

Pigou, A.C. (1932). *The economics of welfare*. London: MacMillan and Co.

Pimentel, D., Acquay, H., Biltonen, M., Rice, P., Silva, M., Nelson, J., Lipner, V., Giordano, S., Horowitz, A. and D'Amore, M. (1992). Environmental and economic costs of pesticide use. *BioScience*, **42**(10), pp.750-760.

Poincelot, R. (1986). *Toward a more sustainable agriculture*. Westport, Connecticut: AVI Publishing Company Inc.

Pretty, J. (1995). *Regenerating agriculture. Policies and practice for sustainability and self-reliance*. London: Earthscan.

Pretty, J.N., Brett, C., Gee, D., Hine, R.E., Mason, C.F., Morison, J.I.L., Raven, H., Rayment, M.D. and van der Bijl, G. (2000). An assessment of the total external costs of UK agriculture. *Agricultural Systems*, 65, pp.113-136.

Quemerais, B., Lemieux, C. and Lum, K. (1994). Concentrations and sources of PCBs and organochlorine pesticides in the St. Lawrence River (Canada) and its tributaries. *Chemosphere*, **29**(3), pp. 591-610.

Quiggin, J. (1997). Discount rates and sustainability. *International Journal of Social Economics*, **24**, pp. 65-90.

Radius Publicite & Promotion. (1994). *Plan strategique de developpement*. A study prepared for the Filiere Biologique au Quebec.

Raghavan, G.S.V, Mckyes, E., Gendron, G., Borglum, B. and Lee, H.H. (1978). The effect of soil compaction on the development and yield of corn. *Canadian Journal of Plant Science*, **58**, pp. 435-443.

Randall, A. (1987). *Resource economics: an economic approach to natural resource and environmental policy*. New York: John Wiley and Sons.

Randall, A. (1999). Why benefits and costs matter. *Choices: The Magazine of Food, Farm and Resource Issues*, **14**(2), pp. 38-41.

Rao, P.K. (2000). *Sustainable development: economics and policy*. Oxford: Blackwell Publishers Ltd.

Ray, A. (1984). *Cost-benefit analysis: issues and methodologies.* A World Bank Publication. Baltimore, MD: The John Hopkins University Press.

Reganold, J.P., Elliot, L.F. and Unger, Y.L. (1987). Long term effects of organic and conventional farming on soil erosion. *Nature*, **330**, pp. 370-372.

Regmi, P.P. and Weber, K.E. (2001). Problems to agricultural sustainability in developing countries and a potential solution: diversity. *International Journal of Social Economics*, **27** (7,8,9,10), pp. 788-801.

Repetto, R. and Cruz, W. (1991). *Accounts overdue: natural resource depreciation in Costa Rica.* Washington, DC: World Resources Institute.

Ribaudo, M. and Hellerstein, D. (1992). *Estimating water quality benefits: theoretical and methodological issues.* Washington, DC: Economic Research Service. Technical Bulletin No. 1808.

Rigby, D. and Caceres, D. (2001). Organic farming and the sustainability of agricultural systems. *Agricultural Systems*, **68**, pp. 21-40.

Romero, R., and Rehman, T. (1987). Natural resource management and the use of multiple criteria decision making techniques: a review. *European Resource and Agricultural Economics*, **14**, pp. 61-89.

Roots, E.F. (1989). *Decision making and sustainable development: some reflections on characteristics and problems. Environment and economy, partners for the future.* Hull, Quebec: Environment Canada. Offices of Science Advisor.

Rose, R. (1990). Valuing environmental services. *Agriculture and Resource Quarterly*, **2**(3), pp. 300-306.

Roy, B. (1992). Science de la decision ou science de l'aide a la decision? *Revue International Systematique*, **6**, pp. 980-1472.

Rutherford, A., Gimby, M., Smith, G., Mair, A. and Coxworth, E. (1992). *Viability of organic farm practices.* Saskatchewan: Saskatchewan Research Council. Publication No. R-1410-6-E-92.

Sassone, P.S. and Schaffer, W.A. (1978). *Cost-benefit analysis: a handbook.* New York: Academic Press.

Schmidt, A.A. (1988). Resource and environmental economics: a discussion. **In**: *Agriculture and rural areas approaching the twenty-first century: challenges for agricultural economics* (R.J. Hildreth, K. Lipton, and K.C. Clayton eds.). Iowa: Iowa State University Press.

Schoney, R.A. and Culver, D. (1991). Economic analysis of sustainable production systems for Saskatchewan. *Canadian Journal of Agricultural Economics*, **39**, pp. 865-876.

Schulze, W.D. and Kneese, A.V. (1981). Risk in benefit cost analysis. *Risk Analysis*, **1**, pp. 81-88.

Schulze, W.D. and Howe, C.W. (1985). Observations on the frontiers and fringes of the neo-classical paradigm. *American Journal of Agricultural Economics*, **67**(5), pp. 1035-1038.

Sellen, D., Tolam, J.H., McLeod, D., Weersink, A. and Yiridoe, E. (1995). A comparison of financial returns during early transition from conventional to organic vegetable production. *Journal of Vegetable Crop Production,* **1**(2), pp. 11-39.

Senate of Canada. (1984). *Soil at risk.* Ottawa: The Standing Committee on Agriculture, Fisheries and Forestry.

Shearer, G., Kohl, D., Wanner, D. and Lockeretz, W. (1981). Crop production costs and returns on mid-western organic farms: 1977 and 1978. *American Journal of Agricultural Economics*, **63**(2), pp. 264-269.

Simonovic, S.P. (2001). Measures of sustainability and their utilization in practical water management planning. **In:** *Proceedings of a symposium held during the Sixth IAHS Scientific Assembly at Maastricht, the Netherlands. July 2001.* IAHS publication no. 268, pp. 3-16.

Simpson, D.A., Fair, M.E. and Poliquin, C. (1991). *Canadian farm operator study: methodology.* Ottawa: Statistics Canada. Health Reports. Volume 2 No. 2.

Soderbaum, P. (1987). Environmental management: a non-traditional approach. *Journal of Economic Issues*, **21**(1), pp. 139-165.

Soderbaum, P. (1990). Neo-classical and institutional approaches to environmental economics. *Journal of Economic Issues*, **2**, pp. 481-492.

Squire, L. and van der Tak, H.G. (1975). *Economic analysis of projects.* Baltimore, MD: The John Hopkins University Press.

Stanhill, G. (1990). The comparative productivity of organic agriculture. *Agriculture Ecosystems and Environment*, **30**, pp. 1-26.

Stanton, J., Olson, D.K., Brock, J.H. and Gordon, R.S. (2001). The environmental and economic feasibility of alternative crops in arid area: considering mesquite in Baja California, Mexico. *Journal of Arid Environments*, **48**, pp. 9-22.

Statistics Canada. (1991). *Human activity and the environment.* Ottawa: Environment and Wealth Accounts Division.

Steiner, R. (1924). *Agriculture. A course of eight lectures.* 3rd Ed. Biodynamic Agricultural Association.

Stirling, A. (1997). Multi-criteria mapping: Mitigating the problems of environmental valuation? **In**: *Valuing nature? Ethics, economics and the environment.* (J. Foster eds.). London: Routledge.

Stolze, M., Piorr, A., Haring, A. and Dabbert, S. (2000). The environmental impact of organic farming in Europe. *Organic Farming in Europe: Economics and Policy.* Volume 6. Hohenheim, Germany: The University of Hohenheim.

Stonehouse, D.P. (1996). Initial technical and economic comparisons of different farming systems in Ontario, Canada. *Biological Agriculture and Horticulture*, **13**, pp. 371-386.

Tabi, M., Tardif, L., Carrier, D., Laflamme, G., and M. Rompre. (1990). Inventaire des *problemes de degradation des sols agricole du Quebec: rapport synthese.* Quebec: Ministere de l'Agriculture, des Pecheries et de l'Alimentation du Quebec. Publication No. 90-130156.

Teague, M.L., Bernardo, D.J. and Mapp, H.P. (1995). Farm-level economic analysis incorporating stochastic environmental risk assessment. *American Journal of Agricultural Economics*, 77(1), pp. 8-19.

Theys, J. (1989). Environmental accounting in development policy: the French experience. In: *Environmental accounting for sustainable development* (Ahmad, Y.J., El Serafy, S. and Lutz E.L. eds.). Washington, DC: The World Bank.

Thomassin, J. (1992). The importance of the agriculture sector to the Canadian economy: an input-output analysis. **In**: *Rural and small town Canada* (R. Bollman ed.). Toronto: Thompson Educational Publications Inc.

Timmons, J.F. and Amos, O.M. Jr. (1982). Economics of soil erosion control with applications to T values. *American Society Agronomy,* **45,** pp. 139-153.

Tisdell, C. (1996). Economic indictors to assess the sustainability of conservation farming projects: an evaluation. *Agriculture, Ecosystems and Environment*, **57**, pp. 117-131.

Trant, D. F. (1989). *Estimating agricultural soil erosion losses from census of agriculture crop coverage data.* Ottawa: Statistics Canada. Environment and Natural Resources Group. Analytical Studies Branch.

Turner, R.K., Pearce, D. and I. Bateman. (1993*). Environmental economics: an elementary introduction.* Baltimore, MD: The John Hopkins University Press.

United States Department of Agriculture (USDA). (1980). *Report and recommendations on organic farming.* Washington, DC: Government Printing Press. Study Team on Organic farming.

United States Department of Agriculture (USDA). (1987). *Agricultural resources: cropland, water and conservation-situation and outlook report.* Washington, DC: Economic Research Service. Report No. AR-8.

United States Department of Agriculture (USDA). (1997). *Predicting soil erosion by water: a guide to conservation planning with the revised universal soil loss equation*

(RUSLE). Washington, DC: Agricultural Research Service. Agriculture Handbook No. 703.

United States Department of Agriculture (USDA). (2000). Glickman announces new proposal for national organic standards. USDA News Release No. 0074.00.

United States Environmental Protection Agency (EPA). (1991). *Proposed guidance specifying management measures for sources of non-point pollution in coastal waters*. Washington, DC.

University of Manchester. (1996). *Adoption of sustainable agricultural technologies*. A survey.

Van Pelt, M.J.F. (1993). Ecologically sustainable development and project appraisal in developing countries. *Ecological Economics*, **7**, pp. 19-42.

Van Vliet, L.J.P., Wall, G.J. and. Dickinson, W.J. (1976). Effects of agricultural land use in potential sheet erosion losses in Southern Ontario. *Canadian Journal of Soil Science*, **56**, pp. 443-451.

Van Vuuren, W. and Fox, G. (1989). Estimating the costs of soil erosion: a comment. *Canadian Journal of Agricultural Economics*, **37**(3), pp. 549-553.

Veeman, T.S. (1991). Sustainable agriculture: an economist's reaction. *Canadian Journal of Agricultural Economics*, **39**(4), pp. 587-590.

Villeveuve, J.P, Banton, O. and Lafrance, P. (1987). *Un nouveau modele pour l'evaluation de la vulnerabilite des aux souterraines a la contamination diffuse par les pesticides*. Quebec: Universite du Quebec.

Von Amsberg, J. (1993). *Project evaluation and the depletion of natural capital: an application of the sustainability principle*. Washington, DC: The World Bank. Environment Working paper No. 56.

Wagner, W.C. (1999). Sustainable agriculture: how to sustain a production system in a changing environment. *International Journal of Parasitology*, **29**, pp. 1-5.

Wagstaff, H. (1987). Husbandry methods and farm systems in industrialised countries which use lower levels of external inputs: a review. *Agriculture Ecosystems and Environment*, **19**, pp. 1-27.

Wall, G.J., Coote, D.R., Pringle, E.A. and Shelton, I.J. (1997). *RUSLEFAC; Revised Universal Soil Loss Equation for Application in Canada: a handbook for estimating soil lloss from water erosion in Canada*. Ottawa, Ontario: Agriculture and Agri-Food Canada. Research Branch, Center for Land and Biological Resources Branch.

Warman, P. (1979). *The basics of green manuring*. Ste. Anne de Bellevue, Quebec: Ecological Agriculture Projects. AP Publication No. 51.

Welch, R.M. and Graham, R.D. (1999). A new paradign for world agriculture: meeting human needs. Productive, sustainable, nutritious. *Fields Crops Research*, **60**, pp.1-10.

Welle, P.G. (1990). Benefit, cost, and beyond: The political economy of benefit-cost analysis. *Atlantic Economic Journal*, **18**(2), pp.79-89.

Weiss, J. (1994). *The economics of project appraisal and the environment*. London: Edward Elgar Publications.

Weitzman, M., (1994). On the environmental discount rate. *Journal of Environmental Economics and Management*, **26**, pp. 200-209.

Weitzman, M., (1998). Why the future should be discounted at its lowest possible rate? *Journal of Environmental Economics and Management*, **36, pp.** 201-208.

Westman, W.E. (1985). *Ecology, impact assessment, and environmental planning*. New York: John Wiley and Sons.

Winnett, A. (1998). Environmental Economics. Lecture notes. Bath, UK: The University of Bath. Department of Economics and International Development.

Wiyo, K.A. (1991). *Measurements and modelling of fertilizer concentrations in subsurace drain flow from a potato field*. Montreal: McGill University. Department of Agricultural Engineering.

Wolf, S.A., Allen, T.F.H. (1995). Recasting alternative agriculture as a management model: the value of adept scaling. *Ecological Economics*, **12**, pp. 5-12.

Woodruff, N.P. and Siddoway, F.H. (1965). *A wind erosion equation*. Soil Science Society (S.S.S.A.P.) 602-608.

World Bank. (1998). Economic analysis and environmental assessment. **In**: *Environmental Assessment Source book*, Insert in Update Binder Chapter 4. Washington, DC: The Environment Department.

World Commission on Environment and Development (WECD). (1987). *Our common future*. Oxford: Oxford University Press.

Van Bers, C. (1990). Personal communication with Henning, J. in 1994. Cited **In**: *Economics of organic farming in Canada*. (N. Lampkin and S. Padel ed.), 1994. Wallingford: CAB International.

Van Mansvelt, J.D. (1997). An interdisciplinary approach to integrate a range of agro-landscape values as proposed by representatives of various disciplines. *Agriculture, ecosystems and Environment*, **63**, pp.233-250.

Van Mansvelt, J.D. and van der Lubbe, M.J. (1999). *Checklist for sustainable landscape management*. Amsterdam: Elsevier.